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In Memoriam

LEONARD RALPH BRAITHWAITE
(1878-1942)

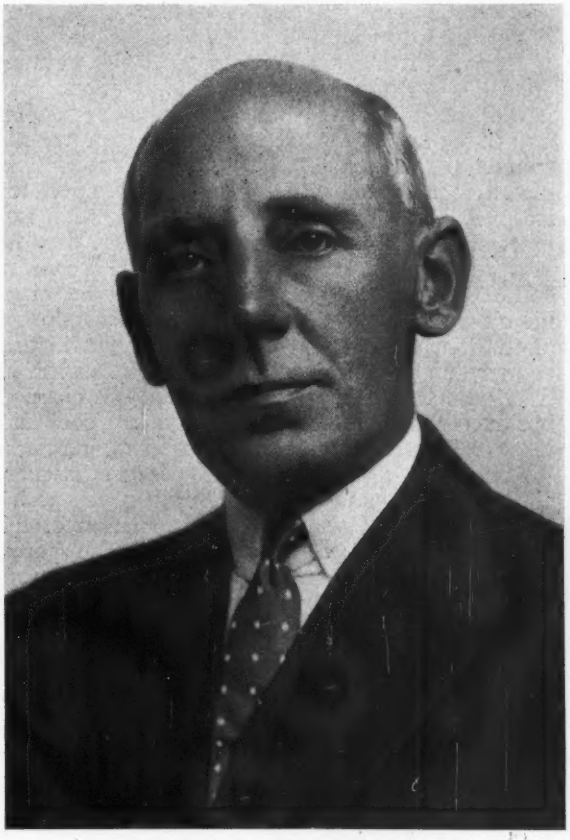
THE death of Leonard Braithwaite on Dec. 18, 1942, after a short illness was a serious loss to British surgery and to the hosts of friends in whom he inspired admiration and affection. His skill as a surgeon was widely known outside the boundaries of his own county, but perhaps only those who were closely associated with him, either as colleagues or as members of bodies on which he served, such as the Council of the Royal College of Surgeons or the Editorial Committee of this JOURNAL, were able fully to appreciate those qualities of mind and spirit which made him much more than a brilliant operator.

The steps by which, after graduating at Leeds with first-class honours in 1903, he steadily advanced through junior appointments until he was appointed Honorary Surgeon to the General Infirmary in 1924 and ultimately to the Chair of Clinical Surgery in the University, have been recorded elsewhere and need no repetition here: it is a picture of him as a surgeon and a man which I shall endeavour to draw.

In his surgical training Braithwaite came under the influence of two men—Edward Ward, whose dresser and house surgeon he was, and Moynihan, to whom he later became Assistant Surgeon at the Infirmary and assistant in private practice.

Ward was a man of great culture and artistic temperament and a skilful and dainty operator who, at a time when surgery was advancing rapidly, would have become much more widely known if his health had not begun to be gravely affected by an infection contracted in the exercise of his profession. These qualities in Ward made a strong appeal to Braithwaite, for in character they had much in common, and his apprenticeship to surgery under a chief whose work was a model of deftness and skill was a fitting preparation for his later association with Moynihan, who became the dominant personality in his life.

About five years later Braithwaite was appointed Assistant Surgeon, in the middle of the decade prior to the last war when Leeds surgery was passing through its most momentous and interesting phase. Moynihan's theatre was



LEONARD RALPH BRAITHWAITE
1878—1942

then the Mecca for distinguished surgeons from all over the world and his brilliance and enthusiasm made these years a landmark in the lives of those

of us who were fortunate enough to be his assistants.

It was not long before Braithwaite became his Assistant Surgeon at the Hospital and assistant in private practice, and his devotion and loyalty to his chief continued unabated until the time of Moynihan's death in 1936. He was Moynihan's confidant in the conception of projects which constituted some of the greatest contributions which he made to the progress of British surgery—the Moynihan Chirurgical Club, the Association of Surgeons of Great Britain and Ireland, and this JOURNAL. At the meeting held in Leeds at which the first of these was conceived, Braithwaite acted as secretary, though owing to limitation of membership he was not elected a member until a good many years had passed.

His close association with Moynihan made it inevitable that abdominal surgery would become his main interest, and his natural ability and inclination made him an apt pupil in the refinements of technique which characterized the work of his master, and when Moynihan retired from the staff the year after Braithwaite's appointment as full surgeon, the quality of the work done showed no deterioration.

His operating was characterized by minute attention to detail, gentle manipulation, and flawless asepsis ; every movement was purposeful, and though there was no suggestion of hurry his sound judgement and sureness of method made him a more speedy operator than the spectator realized. The heroic type of operation did not particularly attract him, though he was capable of dealing with a serious emergency both rapidly and effectively. As an instance may be cited his characteristically brief and simple description of the first completely successful excision in this country of a subclavian aneurysm published in this JOURNAL in 1920. In this case a complication occurred which in the hands of a less cool and resourceful operator might have ended in disaster.

Braithwaite was an ideal clinical teacher, simple, lucid, and practical, and never dull: he was intensely proud of the reputation of his hospital, and by precept and in practice he spared no effort to maintain and enhance the great traditions which had been handed down to him.

In his daily life he was almost an ascetic and his methodical ordering of his days was designed to enable him to give of his very best to those who needed his help.

His contributions to surgical literature were not very numerous ; he never wrote for the sake of writing, but when he did so his articles were clear, well arranged, and thoughtful.

A subject which interested him greatly and on which he published several articles in this JOURNAL was the lymphatic drainage of the ileo-colic angle, both in relation to tuberculous infection and also in its possible bearing upon lesions of the stomach, duodenum, and biliary passages. The last of these articles was the substance of the Moynihan Lecture delivered at the Royal College of Surgeons in 1941, in which he described what he termed the " ileo-gastric syndrome ". In the Bradshaw Lecture only a few weeks before his death he dealt with another aspect of the same question—the part played by biliary regurgitation in the aetiology of peptic ulcer. He was a member of the Editorial Committee of the JOURNAL from 1926 until July, 1939, and was as regular in attendance at its meetings as he was in all things.

Braithwaite's claim to remembrance as a skilful and accomplished surgeon are great indeed, but to those who were privileged to be his friends his memory will hold much more. His enthusiasm for all that was best in surgical practice and training was always evident in the part he took in the discussions of the bodies on which he served, the Faculty and the Board of Management of his own hospital or the Council of the Royal College of Surgeons, of which he had been a member since 1930 and was serving a second year as Vice-President at the time of his death. Modest and unassuming, he nevertheless held opinions which were very definite and he stated them with characteristic deliberation and Yorkshire directness. He had a genius for friendship and for inspiring the willing service and devotion of all who worked for him, house surgeons, sisters and nurses, and all those other servants of the hospital for whom he always had a cheery word. Material success came to him in larger measure than to many men, but no criticism was every heard of the way in which he conducted his professional life : his transparent honesty of purpose earned for him the respect and affection of his colleagues, the general practitioner, and his patients, in whom he always inspired courage and confidence.

In the words of the vote of condolence recorded by the Council of the Royal College of Surgeons and moved so eloquently by Surgeon Rear-Admiral Gordon-Taylor—" His death robs surgery of a famous operator, a great clinician, a notable contributor to the advance of surgical science, an inspiring teacher, a wise counsellor, and a most lovable man ".

CONGENITAL DISLOCATION OF THE HIP*

By HARRY PLATT

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IN RETROSPECT

In the days to come, when the occasion of the Robert Jones Lecture has acquired the patina of long tradition in the calendars of this Royal College, it may be wise for the lecturer to seek counsel in the writings of Wilfred Trotter, the philosopher surgeon of our age. It will be remembered that as Hunterian orator (1932) meditating on what he called "the general case of the commemoration of great men", Trotter reminds us that as commemorative occasions become regularly recurring events, the picture we create of our hero tends to drift steadily away from the true image of the man. Our philosopher surgeon was also profoundly disturbed by the failure of society to celebrate its heroes during their lives, and he looked forward to the day when posthumous honour alone would cease to be regarded as a sufficient recognition of the contributions of the artist and scientist.

We are to-day happily in no such dilemma, for Robert Jones passed from our midst only nine years ago. It is true that already a new surgical generation has emerged, to whom the inspiration of his personal leadership has been denied. But his image is still undimmed in the hearts and minds of a goodly company of surgeons, in the New World and in the Old World, who came under his spell at the most impressionable period of their lives. Nor can it be said of Robert Jones that full and generous acknowledgement of his outstanding gifts, of his contributions, both to the art of surgery and to the social problems of the cripple, was withheld from him during his lifetime.

It is not my purpose to reflect at length on the meaning of the career and work of this great master surgeon. The story of his life has been told by his son-in-law, the late Frederick Watson (1934), in a memoir inspired by affection and filial piety. Frederick Watson, well versed in the art of biography, looked deeply into the life of his hero for the hidden causes which had determined so great an achievement. He found the answer in predestination. And for one who was the son of Ian McLaren, Scottish divine and novelist, this was perhaps an inescapable conclusion.

We must travel warily in the wake of philosopher and theologian. But as we contemplate the life of Robert Jones, we cannot fail to see the paramount influence of epoch—of that accidental conspiracy of events at a certain moment in time—which so often appears to shape the whole future of a man.

There is one experience in the early career of Robert Jones, which, in its far-reaching consequences, might bring reassurance to those who see the life of an individual man as a tiny part of the continuum of a larger design and purpose. In the early 1890's the citizens of the great cotton mart of Manchester vicariously carried through a feat of engineering which brought the sea some 30 miles inland to the heart of the city. During the construction of the Manchester Ship Canal nearly ten thousand men were engaged in the arduous and dangerous work of excavating the new waterway. There must have been men of intelligence and foresight in charge of this undertaking, for not only was the need for a casualty service realized from the first, but Robert Jones, the pupil of H. O. Thomas, was selected to organize and control this service.

When fully developed, the Ship Canal accident service included a chain of first-aid posts and three receiving hospitals—wooden buildings—erected at strategic points between Manchester and Liverpool, each one in charge of a medical officer. The railway which ran along the line of the canal was also used for the transport of injured men. Robert Jones himself often travelled by the little ambulance train when summoned by telegraph to deal with the most serious injuries.

For four years this industrial battlefield provided a wealth of experience both in organization and in the surgical treatment of accidents. In after-years Robert Jones would conjure up from the stores of his memory—for no documented records had been preserved—a vivid account of this chapter in his life. He told us of the large numbers of amputations which were needed for severe crush injuries of the limbs, and how he had tried, but soon abandoned, the guillotine operation. Shock was treated by warmth, morphia, and hot drinks, and the mortality was surprisingly low. The Thomas splint was used, *secundum artem*, for the immediate fixation and transport of lower-limb fractures, thus foreshadowing its introduction some twenty-five years later to the battlefields of France. We thus see how it came to pass that when the Great War of 1914–18 flooded our military hospitals with compound injuries of the limbs, no other British surgeon had so much to offer to his fellow countrymen. This fact now belongs

* The Robert Jones Memorial Lecture, delivered at the Royal College of Surgeons on Nov. 4, 1942.

to the texture of the history of surgery, and its truth cannot be denied.

In 1918, a few months before the end of the war, Robert Jones reached the age of sixty, and

FIG. 303.—Sir Robert Jones in 1918 as Major General, A.M.S.

duly retired from the active staff of the Royal Southern Hospital, Liverpool (*Fig.* 303). Few surgeons welcome retirement under the traditional age limit, and to those in whom physical vigour and mental powers have as yet shown little evidence of deterioration, it is often an occasion to be dreaded. For the man with a message still to be delivered, the sudden eclipse, with the disappearance of opportunity for service, and the rapid decline in private practice, is a galling experience. Robert Jones had special compensations in the two country hospitals he had created at Heswall on Dee and at Baschurch in Shropshire, where for him, and fortunately for British surgery, there was no age limit. But after the arduous years of war, it might have been assumed that he would in due course go the way of all surgeons, quietly taking his leave of the busy scene.

At the age of sixty this remarkable man entered into what was in many respects the most strenuous period of his surgical life, a phase which lasted without any diminution in tempo for fully a decade. It was in the last two years before his death, that we began to perceive a slackening of effort. (*Fig.* 304.) Now for the first time we saw him as an old man; and perhaps for the first time *he* realized that he was mortal. The strenuous years from sixty to seventy must have taken their toll, for he was granted only five years beyond the span allotted to man in the older computations. Not for him the long Indian summer of tranquility and contemplation, vouchsafed to the grand old men of British Medicine of our day; such men as Crichton Browne, Thomas Barlow, Judson Bury, Buckston Browne; and now in this company, Harold Stiles, in his garden at Gullane.

There I must reluctantly leave the picture of the man, and hasten on towards the theme I have chosen for an occasion established to perpetuate his memory. Amongst the host of children who for nearly fifty years made their way to 11, Nelson Street (*Fig.* 305), and to his out-patient clinics at the Royal Southern Hospital (and I recall with gratitude that I was often in that great company) there must have been many victims of that crippling deformity, *congenital dislocation of the hip*. We know that he was amongst the first in this country to practise the Lorenz method of bloodless reduction, and that he treated many hundreds of cases. It is strange, however, that in the long list of his writings, which from 1884 onwards ranged over a wide field of orthopædic surgery, there is no single comprehensive and authoritative article on the subject of congenital

FIG. 304.—Sir Robert Jones, 1930. (*Photograph by G. R. Girdlestone.*)

dislocation of the hip. It is with a sense of inadequacy that I present some observations on a clinical problem which has held my continuous interest for the past twenty-seven years. During

this time I have been able to collect and preserve full records of all the cases I have dealt with, which up to the end of 1941 numbered 349 patients, with 447 dislocations. Details of the material and the methods of treatment adopted are set out in the underlying tables.

FIG. 305.--No. 11, Nelson Street, Liverpool. (Destroyed by enemy action, May, 1941.)

Table I.—ANALYSIS OF CASES TREATED (1914 to 1941—27 years)

349 patients with 447 dislocations

Females	295		
Males	54	Proportion	5 : 1
Unilateral	251		
Bilateral	98		
Age when treated :		Under 15	326
		Over 15	23

Table II.—METHODS OF TREATMENT OF CASES IN *Table I*

Divaricator alone	7		
Manipulative reduction	239		
Open reduction	42	With 'shelf'	22
		Without 'shelf'	20
*Shelf operation	34		
Osteotomy	27		
Other operations (arthrodesis, etc.)	16		

* Includes 12 shelf operations over unreduced dislocations done before 1930.

INTRODUCTION

Congenital dislocation of the hip was known to the Greek School of Medicine. The great corpus of Hippocratic texts contain an accurate word picture of the characteristic gait and posture and a description of the reduction of the dislocation by manual and instrumental traction. Our precise knowledge of the anatomy of the deformity dates from the time of Dupuytren, who in 1826 described the skeletal and muscular anomalies of the untreated dislocation in the child and in the adult. This led to the formation of the remarkable collection of anatomical specimens of congenital hip dislocations to be seen in the Musée Dupuytren in Paris, a collection studied in more modern times by Fairbank, who described a number of new and interesting anatomical features in his Lady Jones Lecture at Liverpool (1930).

One of the most striking facts in relation to the incidence of congenital dislocation of the hip, apart from its much greater frequency in the female, is its curious geographical and racial distribution. The deformity is definitely uncommon in peoples of Anglo-Saxon stock, both in the Old World and in the New World. It is common, on the other hand, in Southern France, Poland, and Czechoslovakia. For the Italian people, amongst whom the incidence is extraordinarily high, congenital dislocation of the hip is a grave social problem. It has been estimated that in Italy, out of one million live births each year, four thousand infants have congenital dislocations; or, to put the matter differently, at any one time four in every thousand persons, or one hundred and eighty thousand individuals in all, are so afflicted (Scaglietti, 1939). The part played by heredity in determining congenital dislocation in the Italian race has been clearly proved. Even in Italy itself there are regional variations in incidence, the deformity being common in the Northern provinces of Lombardy and Emilia, much less common in the South, and rare in the islands. In this connexion the figures of the clinical material of the great Italian orthopædic institutions are most instructive. During the period 1903 to 1936, 8196 congenital hip dislocations were treated in the Rhachitic Institute at Milan. My mind goes back to a September morning in Milan nearly twenty years ago when, with my friend Rowley Bristow of St. Thomas's, we saw nine congenital dislocations reduced by Professor Ricardo Galeazzi. In the Rizzoli Institute of Bologna, 4990 cases were treated between 1899 and 1938—a thirty-nine-year period. It is to the Director of this world-famous orthopædic clinic, the incomparable Vittorio Putti—who died in his prime a few months after the entry of Italy into the World War—that we are indebted for so much of our present-day knowledge on this subject. (*Fig.* 306.) The contributions of Putti on congenital dislocation of the hip will be part of the enduring heritage of orthopædic surgeons of the future. His superb atlas on the anatomy of the dislocation in the infant and young child, published in 1935, with its unique dissections, is in the true line of descent from the classic atlases of the famous Italian anatomists of Padua and Bologna. His work on the recognition of congenital dislocation in the young infant, and its treatment by the method of gradual reduction, opened a new and fascinating chapter in orthopædic surgery. At this moment, through the veil and mists of a World War, it is difficult for us to realize that Putti has also joined the great

procession. And in the days of peace, when surgeons once more clasp hands in renewal of international friendships, we shall sorely miss the inspiring presence of this great Italian surgeon,

FIG. 306.—Vittorio Putti, 1880–1940.

savant, and bibliophile, at the time of his death the acknowledged intellectual leader of orthopædic surgery, and one who in affection and humility had called Robert Jones master.

MANIPULATIVE REDUCTION

The reduction of a congenital hip dislocation by manipulation followed by a period of fixation in plaster-of-Paris—a practice introduced over forty years ago—is still the method of choice, except in the dislocations discovered in the young infant before the stage of walking. The name of Adolf Lorenz is inseparably attached to the technique of manipulative reduction, although between the years 1886 and 1896 Paci, an Italian surgeon, using great and often dangerous force, had successfully reduced a number of dislocations by the bloodless method. From 1900 onwards the method as practised and taught by Lorenz spread rapidly throughout the surgical world. Lorenz had by that time become one of the outstanding figures of the Vienna school, a man of great physical strength, handsome, debonair, and one of the supreme egotists amongst surgeons, as his autobiography *Mein Leben*, written in 1936, at the age of 82, bears witness. Lorenz was not content to teach from Vienna alone. He began to travel widely, and he demonstrated the technique of bloodless reduction before large gatherings of surgeons in many lands. These triumphal journeys were not without material reward ! On Jan. 10, 1903, on the invitation of Robert Jones, Lorenz appeared in Liverpool, where seventeen cases had been collected for him to treat. As described by Robert Jones with gusto in later years, it was a dramatic performance. Four days later, the London orthopædic surgeons, not to be outdone by the provinces, entertained the Vienna surgeon at the old City Orthopædic Hospital, where two cases were submitted for reduction. In the audience on that occasion was a young London surgeon—my close friend and colleague H. A. T. Fairbank—who later in the year reduced the first of a long series of congenital dislocations at the Great Ormond Street Children's Hospital, and whose experience in the treatment of the deformity in this country is so far unrivalled. Mr. Fairbank tells me that he has now dealt with 473 dislocations in 358 patients. It will be seen from my own figures of 447 dislocations in 349 patients that I am running close behind him !

Manipulative reduction as practised to-day differs in many respects from the robust technique of Lorenz. In the first place we have learned the absolute need for gentleness. We have also learned not to attempt manipulation in children well beyond the so-called favourable age period, nor in those dislocations in young children where there is reason to believe there are formidable anatomical obstacles to the reposition of the femoral head in the rudimentary socket. Disasters such as sciatic-nerve palsy, fracture of the femoral shaft, separation of the upper femoral epiphysis, not infrequently experienced in the past when great force was used, are now almost unknown.

Results of Manipulative Reduction.—It might reasonably have been expected that our knowledge concerning the late results of manipulative reduction would by this time have become both extensive and precise. In *Great Britain*, owing to the wide dispersal of cases of this uncommon deformity amongst many hospitals, few individual surgeons have been able to treat and to follow up any large series. In 1922 Fairbank presented an analysis of the five-year results in 146 cases (170 hips) treated by him before 1914. His chief conclusions were: (1) that in dislocations under the age of 4, anatomical cures could be expected in 75 per cent of unilateral cases and in 50 per cent of the bilateral cases; and (2) that in these hips good function was likely to be preserved for many years. Laming Evans (1930) found good or perfect functional results in 22 out of 25 cases (36 hips) examined ten years or more since the time of reduction, with a congruent joint or concentric reduction in 24 hips. In the *United States of America*, where the incidence of the deformity is also low, except in regions where the population is predominantly

of Italian or Mid-European stock, there has been the same difficulty in tracing late results on a large scale. Despite this handicap the available material has been admirably documented and analysed (Goldthwait, 1921; Ridlon, 1921; Stephens, 1928; Kidner, 1935; Farrell and Howarth, 1935).

A number of more comprehensive surveys conducted within the last few years have provided a considerable addition to our body of knowledge. Of inestimable value are the reports prepared by Scaglietti (1939)—Putti's most brilliant pupil and intellectual heir—Leveuf (1939), and Schede (1939), for the ill-fated Congress of the International Society of Orthopædic Surgery which was to have been held in Berlin during the first week in September, 1939. There is also the recent analysis (1941) by Severin, of 330 patients treated in Stockholm during a period of 27 years, in the Orthopædic Institute so long the scene of the activities of the genial Patrik Haglund. Scaglietti's report is a brilliant monograph on the subject of congenital dislocation of the hip from almost every aspect. It is based on an analysis of 15,272 cases treated in the leading Italian Orthopædic Clinics between the years 1899 and 1938. The material from the Rizzoli Institute alone provided 3628 fully documented cases for the study of the late results of manipulative reduction, and from which it appears that a highly satisfactory anatomical and functional result had been achieved in 45 per cent to 50 per cent of the cases. Leveuf found good anatomical and functional results in only 25 per cent of the 600 cases submitted for review, and he was impressed by the deterioration of function shown by many of the hip-joints after the period of growth had finished. Schede, whose report is based mainly on Lange's Munich series of 1500 cases, together with 562 personal cases treated in Leipzig, found that 50 per cent of closed reductions were anatomical 'cures'.

Table III.—Late Functional and Anatomical Results in 62 Hip-joints in 50 Patients treated by Manipulative Reduction

(Examined more than 10 years after reduction—longest period 25 years.)

Unilateral 38 } 62 hip-joints
Bilateral 12 }
Age of reduction, 8 months to 11 years.
Favourable age { Under 3 — 27 cases; 3 to 5 — 15 „
Unfavourable age Over 5 — 8 „

	Group 1 F/1 A/1		*Group 2* F/2 A/2		*Group 3* F/3 A/3		*Group 4* F/4 A/4	
Functional	Perfect or excellent	25	Very good or good	21	Fair	14	Poor	2
Anatomical	Full congruity	10	Slight incongruity	19	Moderate incongruity (subluxation, coxa vara)	21	Gross deformation (dislocation, etc.)	12

46 out of 62 hips—functional result very satisfactory.
29 „ „ 62 „ —anatomical result very good.

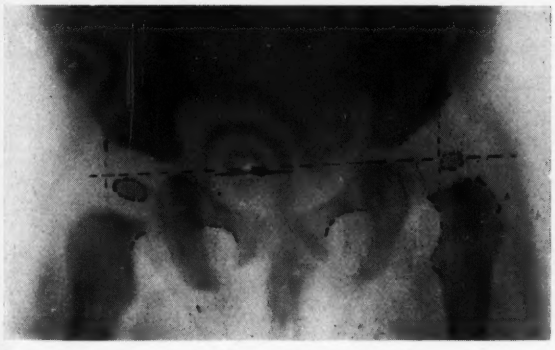


Fig. 307.—A. A. (F.), aged 8 months. Congenital dislocation of left hip. Before reduction.

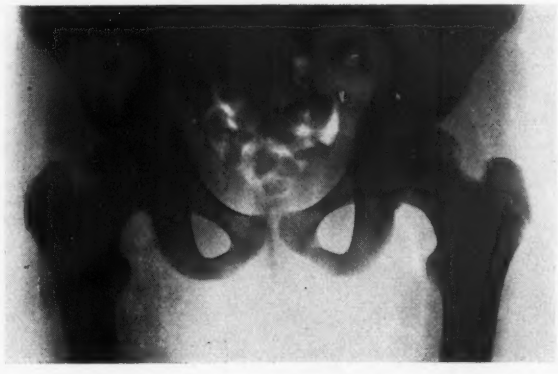


Fig. 308.—Same case. Result 11 years after manipulative reduction. Perfect anatomical and functional result.

Severin's review of the Stockholm material is an admirable document. He has been able to re-examine 317 cases, with 414 hip-joints, more than 5 years from the time of reduction, the longest period being 27 years. The anatomical results, assessed on a radiographic estimate of the degree of dysplasia of the hip-socket roof, are somewhat chastening. Perfect or excellent results were

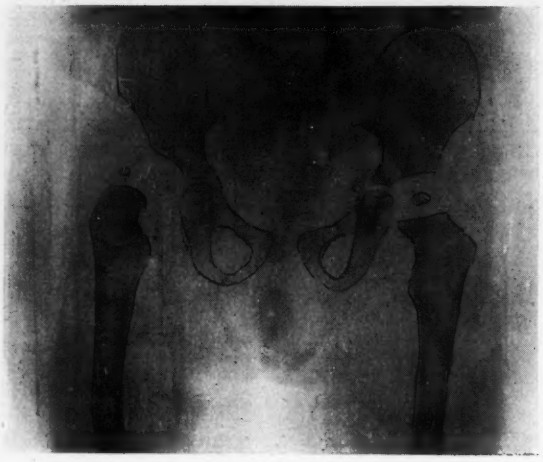


FIG. 309.—D. C. (F.), aged 1 year 4 months. Congenital dislocation of left hip.

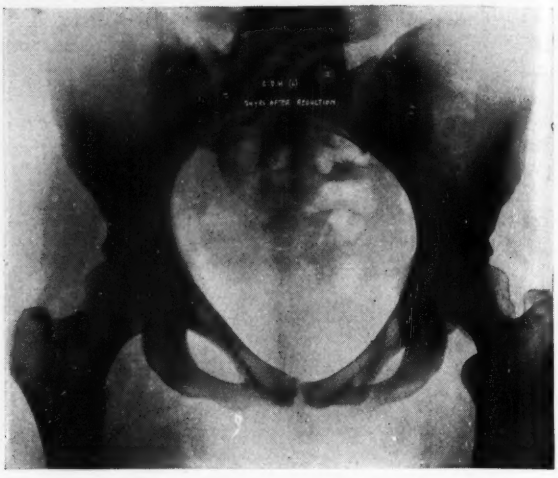


FIG. 310.—Same case 24 years after manipulative reduction. Functional result, excellent; anatomical result, slight incongruity.

FIG. 311.—L. McK. (F.), aged 6 years (unfavourable age). Congenital dislocation of right and left hips.

FIG. 312.—Same case 19 years after manipulative reduction. Functional result: Left, excellent; Right, very good.

seen in 11 per cent of the cases only; 43 per cent showed definite evidence of residual *subluxation*; and in 34 per cent there was a state of actual *dislocation*. The *functional* results were, as one would expect, much better: *perfect* in 25 per cent and *good* in 40 per cent. The tendency to deterioration in cases with a poor anatomical result was also noticed.

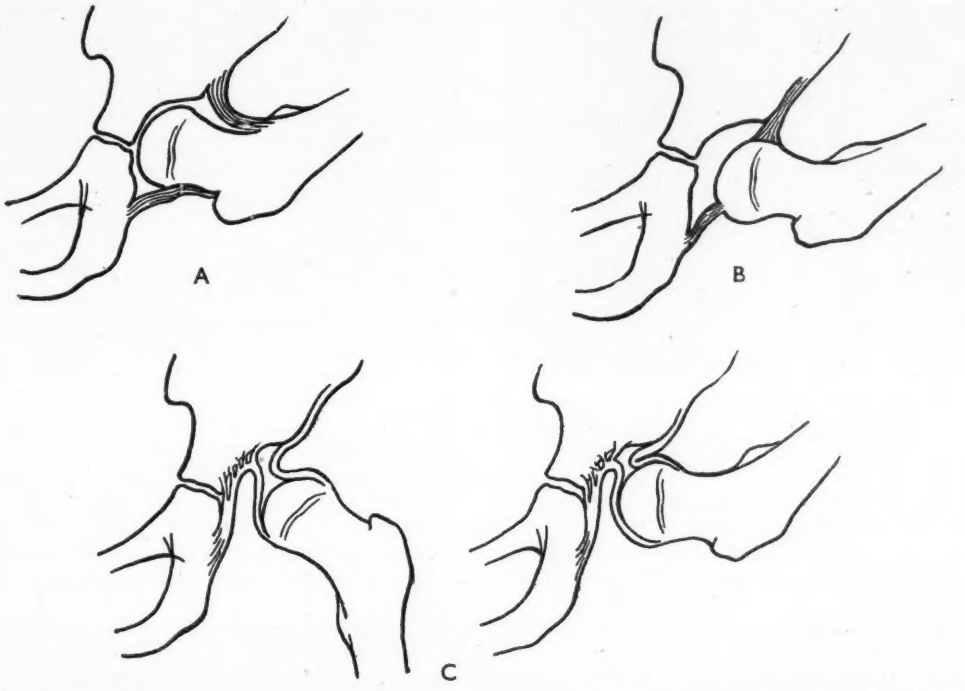


FIG. 313.—Congenital dislocation of hip. Anomalies of joint capsule (Putti). A, Capsule attached to base of neck. Complete reduction. B, Capsule attached to head. Incomplete reduction. C, Capsule adherent to socket floor. Incomplete reduction.

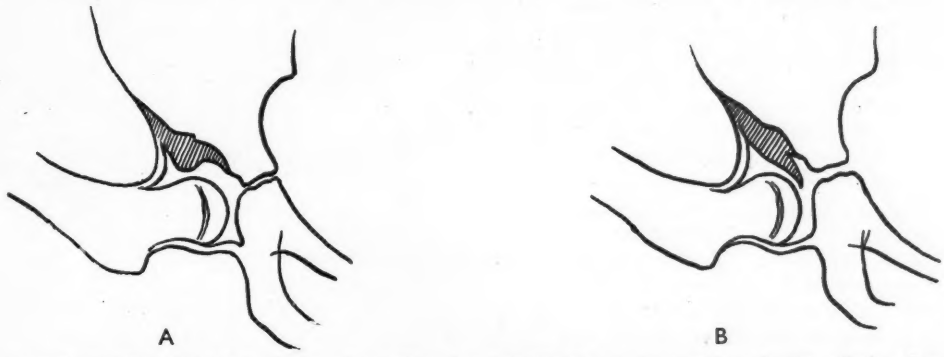


FIG. 314.—Congenital dislocation of hip. Anomalies of capsule (Putti). A, Concentric reduction; limbus forms no obstacle. B, Complete reduction blocked by limbus.

Personal Material.—In my own comparatively small series of 349 cases of congenital hip dislocation it has been possible to re-examine only 104 cases, presenting 133 hip-joints, five years and over after the time of reduction. Repeated efforts have been made to trace every single patient, but many of the earlier cases are now lost owing to shifting populations. Of these 104 cases, 50 patients, with 62 hip-joints, have been re-examined 10 years or more since reduction, the longest period of observation being 25 years. The main facts of this analysis are presented in the table on p. 295.

It will be seen that 46 out of 62 hip-joints showed good or excellent *function*, but that a good or satisfactory *anatomical* result was obtained in only 29 of them. These figures cannot be used as averages, for the number of cases is too small, and they are an 'accidental' collection.

They provide, however, ample material for commentary on the problem under consideration. Both the five-year and ten-year results confirm the well-established fact that the highest quality of anatomical and functional results are seen in the young children treated well within the limits of the favourable age period. At the same time,

a number of surprisingly good results have been observed in older children. I find no convincing evidence of any general tendency to progressive deterioration in function during the years of growth as noted by Leveuf and Schede. The quality of the results recorded at the end of the first five-year period show little or no change in the same patients examined five years later (*Figs.* 307–312).

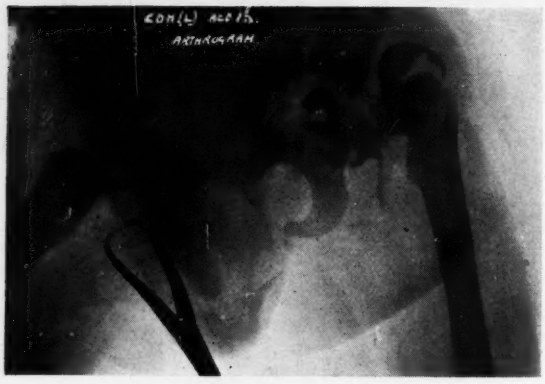


FIG. 315.—A. R. (M.), aged 1 year 5 months. Congenital dislocation of left hip. Arthrogram. Note suggestion of isthmus and pooling of contrast medium in socket. (Arthrography technique: 3 c.c. perabrodil diluted with saline.)

Causes of Failure and Disappointing Results.—

Extrinsic Causes.—The considerable number of indifferent anatomical results which have followed 'successful' reductions in children within the favourable age period continue to give the experienced surgeon cause for dissatisfaction. Complete failure to reduce the dislocation, or to obtain a satisfactory anatomical and functional result after reduction, may, of course, be due to technical reasons—bad selection of cases; choice of the wrong method; lack of familiarity with manipulative technique; or inadequate or inefficient after-treatment. These are for the most part avoidable causes. A very small proportion of dislocations are completely irreducible by any method, even in the young child. These are "primitive luxations" (Putti), in which there is a profound malformation of all hip-joint structures. But there are also a small number of dislocations in young children, not primitive luxations, in which manipulation is hazardous and likely to fail, and which in my view can be more safely treated by open reduction.

Intrinsic Causes.—We must realize that in every congenital hip dislocation there are intrinsic defects both in structure and in capacity for growth which may go far to determine success or failure. (1) There are first of all certain anomalies of the *joint capsule*—attachment of the capsule to the femoral head, adherence of the capsule to the socket floor, or an abnormally developed limbus—which may prevent the reposition of the femoral head into the depth of the socket (*Figs.* 313, 314). In such cases we may achieve a false reduction which at a later stage proves to be a subluxation. There is also the *isthmus* or hour-glass contraction of the capsule which is often a true barrier to reduction (*Fig.* 315). (2) Certain *skeletal* anomalies must also be reckoned with. (*a*) Excessive *anteversion* of the femoral neck has often been cited as a factor opposing reduction or as a cause of re-dislocation, and operative procedures have been devised for its correction, but this view has found little sustained support. (*b*) A more important factor is the failure of the socket roof to develop and fully contain the replaced femoral head. The fickle behaviour of the acetabular roof is well recognized, but it is unwise to assume at too early a stage in treatment that failure is inevitable. (*c*) More important still is the uncommon complication of *osteochondritis*, that remarkable growth disturbance which leads to permanent and often severe deformation of the femoral head, neck, and the hip socket—coxa plana and coxa vara (*Figs.* 316, 317). Osteochondritis is not necessarily due to injury; it has been observed after easy reductions in young children, and in some cases the very early changes in the femoral epiphysis have been detected in the radiographs taken before reduction. The cause is obscure. Constitutional factors, congenital absence of the ligamentum teres, injury to this ligament during reduction or by the pressure of the reduced femoral head, have been

FIG. 316.—P. C. (M.), aged 1 year 7 months. Congenital dislocation of left hip. Radiograph taken 4 years and 3 months after manipulative reduction, showing well-marked osteochondritis in femoral epiphysis.

suggested as responsible for the disturbance of the vascular supply which initiates the characteristic sequence of changes. Osteochondritis should be suspected if after the stage of plaster fixation the reduced hip exhibits persistent muscle spasm with or without pain. The recognition of this important complication calls for the postponement of weight-bearing, and complete rest with traction is often desirable during the stage when the hip is irritable.

If, then, the intrinsic anatomy of the dislocated hip is concerned in determining the quality of the results following reduction, it is desirable that the special features of each hip should if possible be ascertained before treatment is begun. How can we recognize hidden anomalies? Useful information can be gleaned from a careful study of the clinical signs and radiographs. In the future we may be able to obtain even more precise information from *arthrography* as used in Stockholm by Severin (1939), and Wiberg (1939). Arthrography has so far given us a striking demonstration of the ramifications of the synovial cavity of the normal hip, but greater experience is required before we can interpret with confidence the arthrograms of a defective hip. In time we may learn to recognize anomalies of the limbus and the existence of the isthmus.

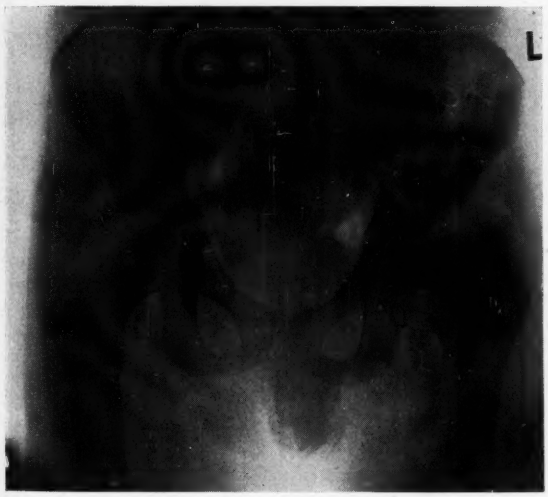


FIG. 317.—Same case as in *Fig.* 316, 8 years after manipulative reduction—osteochondritis, resulting in gross deformity of femoral head, with subluxation.

Residual Subluxations following Reduction.—A residual subluxation following reduction is recognized either in the early stages of mobilization before weight-bearing or at a later stage when the child has walked for some time. As we know spontaneous correction to be an uncommon event, positive action is called for. The choice lies between a further manipulative reduction followed by a short period of fixation in plaster in the standard position of 90° abduction-flexion; a period of traction in abduction; or a direct operative attack on the intrinsic socket defect—i.e., the *construction of an acetabular lip or shelf*. In the young child conservative procedures should first be tried in the hope that the stimulus of the concentrically replaced head will cause the acetabulum to display a latent capacity for reconstruction. The *shelf operation*, attractive in theory but difficult in execution, has been practised far too indiscriminately. Many shelf operations are in my judgement of pictorial value only—merely anatomical exercises in one plane. This is true of some of my own earlier operations. I am not convinced that a shelf which merely prolongs a sloping roof over an eccentrically placed head, contributes materially to the stability or function of the hip. The same criticism is applicable to the construction of a shelf over an unreduced dislocation, which a number of eminent authorities continue to regard as a sound procedure (Dickson, 1935). The essential basis of the shelf operation is that the socket roof should be lowered over a concentrically replaced head (*Figs.* 318–322). This is a formidable undertaking in the young child, and there is the risk of interference with future acetabular growth. In subluxations in older children it may be necessary to open the joint capsule in order to reduce the head completely. The operation then comes into the category of late *open reduction*.

The shelf operation also has a limited place in the treatment of primary subluxations in older children or in the young adult. But for residual subluxations it is at the best a makeshift, which in due course will tend to disappear from our repertoire as we learn to achieve a greater proportion of concentric and stable reductions. My own small series of shelf operations for subluxation does not lend itself to any form of detailed analysis.

OPEN REDUCTION

The open reduction of congenital hip dislocations was practised in Italy as long ago as 1880 by Poggi, who in older children deepened the socket and reshaped the femoral head. The famous Hoffa, and Lorenz himself, both tried the method but abandoned it owing to failures and the disastrous results of infection. As an operation of first instance, open reduction was revived in more recent times by Galloway, of Winnipeg, who advocated its use in young children in preference to closed reduction, and who in 1926 reported on the excellent anatomical and functional results obtained in 72 cases.

In the 4990 cases of the Rizzoli Institute, open reduction was used in 116 cases, the majority of these operations being done between 1899 and 1915, before Putti had perfected the technique. It is notable that in 6 of these only was a shelf constructed at the same time. Although good anatomical results were observed in only 25 per cent of these cases, Scaglietti suggests in his report (1939) that when a larger number of cases becomes available for study, the late results may prove to rival those of closed reduction. From

FIG. 318.—R. E. (F.), aged 6 years. Congenital dislocation of right hip.

FIG. 319.—Same case 7 months after manipulative reduction. Concentric apposition; defective roof socket.

FIG. 320.—Same case 8½ months after manipulative reduction. Hip beginning to subluxate.

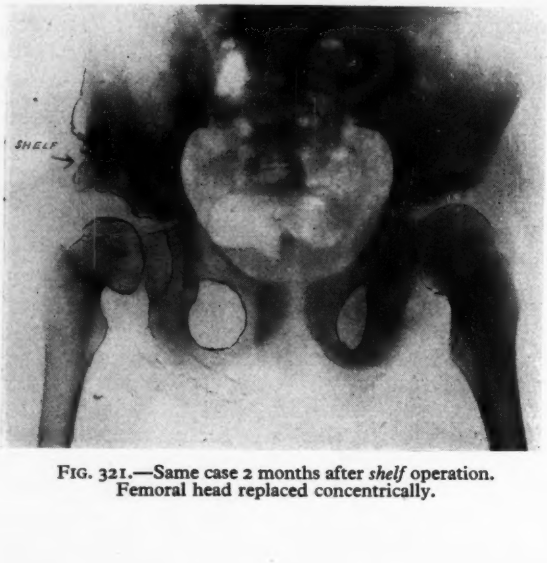


FIG. 321.—Same case 2 months after *shelf* operation. Femoral head replaced concentrically.

FIG. 322.—Same case 8 years after shelf operation. Functional result, excellent.

France, Leveuf (1939) reports good anatomical results in 40 per cent, the best results being seen when the reduction was combined with a shelf or other reconstructive procedure. Schede (1939) reduction has an established place in the treatment of congenital dislocation of the hip, and that the indications for its use are: (1) As a primary operation in certain dislocations in young children

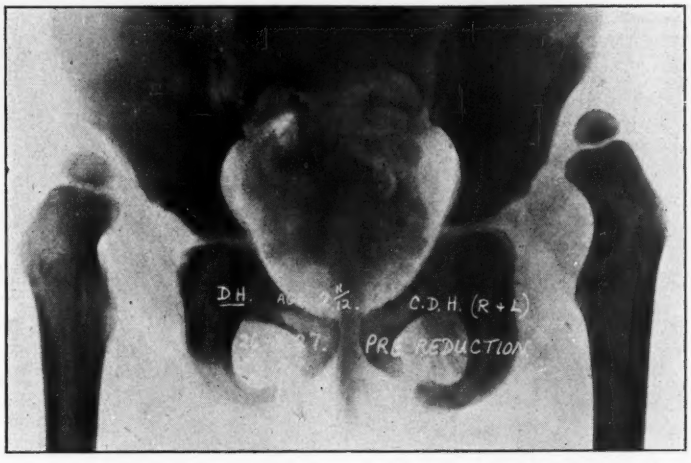


FIG. 323.—D. H. (F.), aged 2 years 11 months. Congenital dislocation of right and left hips.

FIG. 324.—Same case 10 years after open reduction, following failure of manipulation. Right hip: functional result, almost perfect. Left hip: functional result, good.

voices the general attitude of the German school of orthopædic surgeons in the statement that the open operation is rarely indicated.

The 42 open reductions in my own series have been performed at different age periods, and on joints both favourable and unfavourable. They include a few cases which have been followed up over a long period, and in which the hips so far have withstood the stresses of activity without signs of deterioration (*Figs.* 323–326). My experience leads me to conclude that open during the favourable age period, when there is evidence that the intrinsic obstacles to reduction are formidable; (2) In older children beyond the favourable age period, where closed reduction is obviously impracticable or too dangerous; and (3) In residual subluxations following closed reduction in older children. It will be agreed that good anatomical and functional results cannot be guaranteed in hip-joints already damaged by repeated unsuccessful efforts to reduce the dislocation by manipulation.

The operation is one of considerable delicacy. Accuracy of approach, absolute hæmostasis, and the utmost gentleness in replacing the femoral head into the socket, are essential. The capsular isthmus may need dilatation or division in its long axis. The ligamentum teres, with its potentially important arterial supply to the femoral head, should be carefully preserved whenever possible. I have found that a considerable proportion of hips are stable immediately after the head is reduced, and that the addition of a shelf is often unnecessary. This makes for a short operation, almost completely devoid of the risk of shock. The after-treatment is important in determining ultimate success. A short period of fixation in plaster (eight or ten weeks) in the position of 90° abduction-flexion (sometimes with internal rotation) is desirable. After this the hip is gradually brought down by continuous traction, and the stage of mobilization then begins. Weight-bearing should be postponed until there is radiographic evidence that no growth disturbance has been set up in the femoral head or socket.

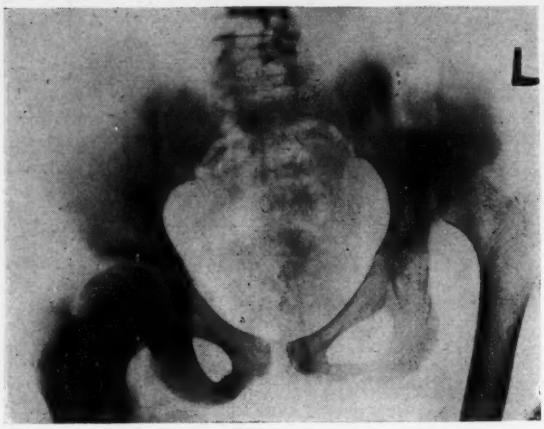


FIG. 325.—A. D. (F.), aged 11½ years. Congenital dislocation of left hip. (Age and anatomical conditions unfavourable.)

FIG. 326.—Same case 10 years after open reduction. Function, good; has worked for 7 years in cotton mill without discomfort.

FIG. 327.—I. L. (F.), aged 9 months. Congenital dislocation of left hip. Note asymmetry of skin creases, shortening, limitation of abduction. (Both shortening and asymmetry of the skin creases may occasionally be seen in an infant in whom there is no dislocation of the hip.)

TREATMENT OF THE DISLOCATION IN THE YOUNG INFANT

Reference has already been made to the work of the Bologna school on the treatment of congenital hip dislocations in the first year of life.

FIG. 328.—S. B. (F.), aged 5 months. Congenital dislocation of left hip.

FIG. 329.—Same case on divaricator.

The clinical picture of the dislocation in the young infant, first described by Putti (1927)—asymmetry of the lower limbs and of the skin creases; shortening; limitation of abduction—(*Fig.* 327); has for some years been broadcast in pamphlet form in Italy amongst the medical profession, nurses, midwives, health visitors, and social workers. This propaganda has already borne fruit, for at the Rizzoli Institute, by the end of 1938, 777 dislocations in infants under the age of one year had been treated by the method of gradual abduction. This involves the use of the simple apparatus known as the *divaricator*, on which the baby is fixed and from which she is removed at regular times for washing and nursing purposes. Complete reduction is obtained after some weeks, or even months, the position of the femoral head being checked by X rays at intervals.

FIG. 330.—Same case after 7½ months on divaricator.

FIG. 331.—Same case after 7 months on divaricator —hip now reduced.

FIG. 332.—Same case 8 years after treatment on divaricator. Functional and anatomical result perfect.

In the Bologna series, 94 per cent of the cases showed excellent or perfect anatomical and functional results—a remarkable achievement.

Our opportunities, alas, of early diagnosis and treatment in this uncommon congenital deformity will always be few. My own experience of the divaricator treatment has been confined to 13 cases (including 2 cases in which treatment was begun this year). Most of these have been treated in my children's orthopædic hospital on the shores of Lake Windermere, where the nursing staff have become expert in the care of the infant on the divaricator. Of these 13 cases, 1, a primitive luxation, was a complete failure, and later defied all attempts to reduce by manipulation. In 4 cases the divaricator was abandoned for reasons of inconvenience after a trial of some weeks, and the dislocations were later reduced by gentle manipulation under anæsthesia, followed by the usual fixation in plaster. In the remaining 8 cases the method has been most satisfactory. The first child of this series treated on the divaricator now at the end of *eight years* shows a perfect anatomical and functional result (*Figs.* 328–332).

CONCLUSION

There are other aspects of the subject of congenital dislocation of the hip to which brief reference only has been made, but which might provide a valuable text for the Robert Jones Lecturer on a future commemorative occasion. There is the problem of the reduced hip with a residual subluxation or deformity showing the clinical signs of deterioration in the adolescent or adult. There is also the related problem of the unreduced dislocation giving rise to trouble after years of comparative comfort and useful function. These are problems of economic and social importance. It is true that we have at our disposal operative measures whereby such disabilities can be mitigated, but to the surgeon who is deeply and continuously interested in the treatment of congenital dislocation of the hip these unfortunate individuals are lost causes.

The task which lies before us is to make increasingly possible the recognition and treatment of the dislocation in the young child before the stage of walking. We must follow the lead of the Bologna school in our teaching and propaganda. The day may be remote when, with early diagnosis, reduction by gradual abduction, with its brilliant anatomical and functional results, will become the accepted routine. In the meantime, skill in the difficult art of manipulative reduction will still be needed. Unless new genes are introduced into our population, congenital dislocation of the hip will continue to be an uncommon deformity in Great Britain. The wide dispersal of these children in many different hospital clinics is therefore to be deprecated. We must preach the doctrine of the importance of segregation, so that this scanty material can be directed towards a limited number of centres, where judgement, skill, and continuity of experience in *all* methods of treatment are available. In this way, and in this way only, can British surgery in the future contribute its quota towards the advancement of knowledge in this important and potentially serious crippling deformity.

And the few, the happy few, to whom this high endeavour is entrusted, may perhaps find inspiration in the words of the motto of Mary Stuart, Queen of Scots :—

"In my end is my beginning."

REFERENCES

DICKSON, F., *Jour. Bone and Joint Surg.*, 1935, **17**, 1.
EVANS, E. L., *Brit. Med. Jour.*, 1930, 2, 1035.
FAIRBANK, H. A. T., *Brit. Jour. Surg.*, 1930, **17**, 67.
FAIRBANK, H. A. T., *Ibid.*, 1922, **10**, 37.
FARRELL, B. P., and HOWARTH, M. B., *Jour. Bone and Joint Surg.*, 1935, **17**, 1.
GALLOWAY, H. P., *Ibid.*, 1926, **3**, 3.
GOLDTHWAIT, J. E., *Jour. Orthop. Surg.*, 1921, **3**, 8.
KIDNER, F. C., *Jour. Bone and Joint Surg.*, 1935, **17**, 1.
LEVEUF, J., *Report on Congenital Dislocation of the Hip for 4th Congress—International Society of Orthopædic Surgery*, 1939. Brussels.
LORENZ, A., *My Life and Work*, 1936. New York: Scribners.
PUTTI, V., *Anatomico della Lussazione Congenita dell' Anca*, 1935. Bologna: Capelli.
PUTTI, V., *Arch. ital. di Chir.*, 1927, **18**, 653.
RIDLON, JOHN, *Jour. Orthop. Surg.*, 1921, **3**, 8.
SCAGLIETTI, O., *Report on Congenital Dislocation of the Hip for 4th Congress—International Society of Orthopædic Surgery*, 1939. Brussels.
SCHEDE, F., *Ibid.*
SEVERIN, E., *Acta chir. Scand.*, 1941, **84**, supp. 63.
SEVERIN, E., *Jour. Bone and Joint Surg.*, 1939, **21**, 2.
STEPHENS, R., *Ibid.*, 1928, **10**, 3.
TROTTER, W., *Hunterian Oration* (1932) *in Collected Papers*. 1941. Oxford University Press.
WATSON, F., *The Life of Sir Robert Jones*, 1934. London: Hodder & Stoughton.
WIBERG, G., *Acta chir. Scand.*, 1939, supp. 58.

A NEW FREE GRAFT
APPLIED TO THE RECONSTRUCTION OF THE NOSTRIL

By Sir HAROLD GILLIES, C.B.E.

In making a new nose after its destruction by accident or disease three methods have been in constant use for the formation of the nostril margin: (1) A flap is turned in from the neighbourhood so that it forms the lining of the nostril, but requires a considerable waiting period between the graft and the making of the nose. The new nostril is liable to be lacking in support and apt to contract and form an atresia of the naris. (3) An extra piece of the covering flap is

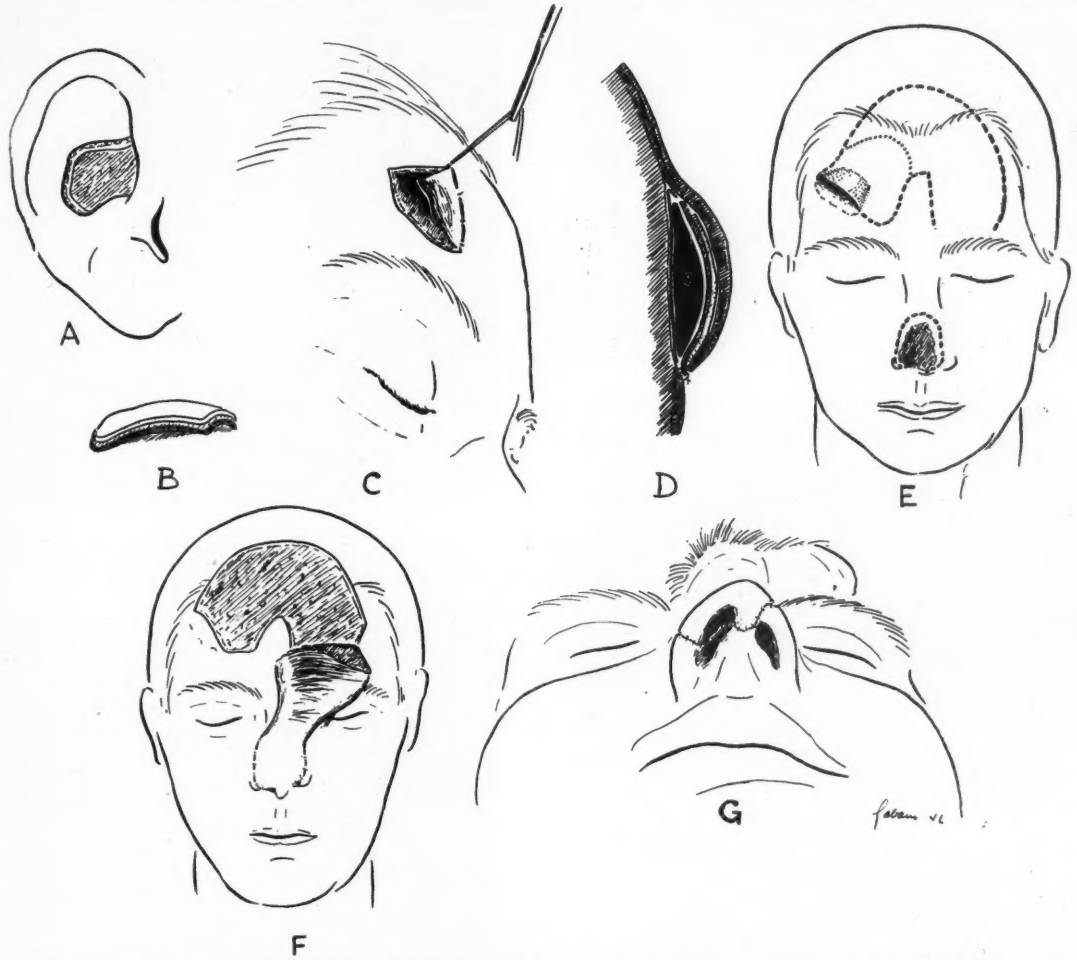


Fig. 333.—A, The donor area of the ear which is skin grafted; B, The chondro-cutaneous graft; C, Implantation into forehead—an ordinary skin-graft is also applied to the area from which the flap has been raised; D, Diagram of pressure dressing; E, Up and down forehead flap; F, Pedicle in place; G, Completion.

which is joined to the covering flap along the margin. Certain well-known disadvantages arise from this method. Trophic troubles are liable to occur in the turned-in flap, and marginal necrosis where the stitches have been placed will also spoil the effect. (2) A free skin-graft is placed under that part of the forehead that is designed to make the nostril margin as well as other parts of the nasal lining. This is fairly satisfactory, turned in so that the margin is formed by a double portion of the external flap. This forms a very excellent looking nostril in many cases, but again is lacking in support, is liable to a certain amount of necrosis owing to the doubling-in process, and when completed forms rather a thickened margin as compared with the natural. The aperture of the nostril is again liable to be on the short or stenosed side. Many attempts have been made

to support one or all of these methods by means of cartilage strips, but none of these has appeared very satisfactory or become a general technique.

On looking round for an improvement in the method of making a nostril, the fact that the

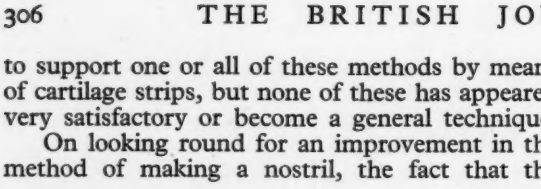


FIG. 334.—Example of chondro-cutaneous graft applied to a chest-flap designed to make a new nose. (*Mr. J. B. Cuthbert.*)

normal nostril is lined by a very thin piece of skin closely adherent to a thin piece of cartilage was an intriguing observation. Such a piece of

FIG. 335.—Loss of right ala and lobule.

skin and cartilage is readily available in the concha of the normal ear. The skin on the front of the concha is very closely adherent to the thin cartilage, and the curve of the cartilage is similar to that required in making a nostril. In order to prove that such a piece of cartilage and skin grafted under the covering flap would make a good nostril, three rhinoplasties were done in which the covering flap was made to approach the ear in such a way as to pick up this combination of cartilage and skin as a living flap. When the cartilage and skin has adhered to the living flap it could then safely be divided from its remaining attachment to the ear and left adhering to the covering flap. Having proved its general value it remained to make the apparently risky procedure of cutting

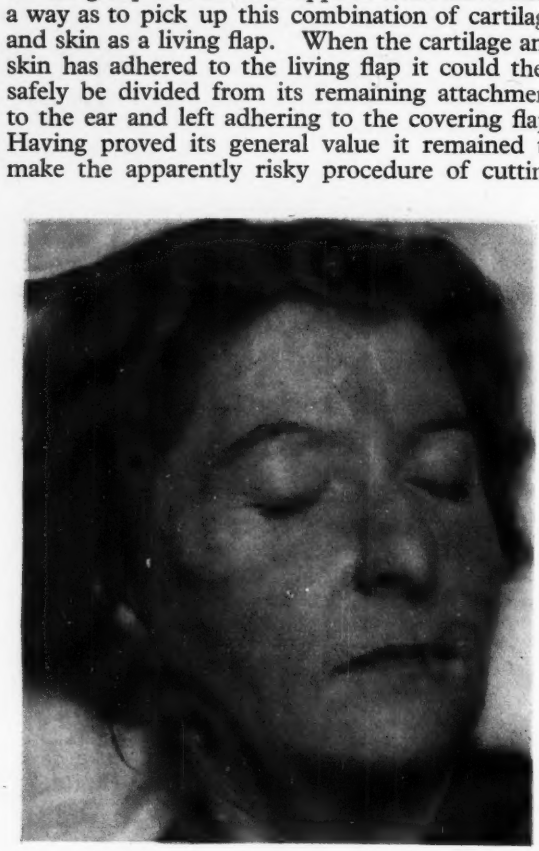


FIG. 336.—Repair by forehead flap rhinoplasty with chondro-cutaneous graft for lining of ala.

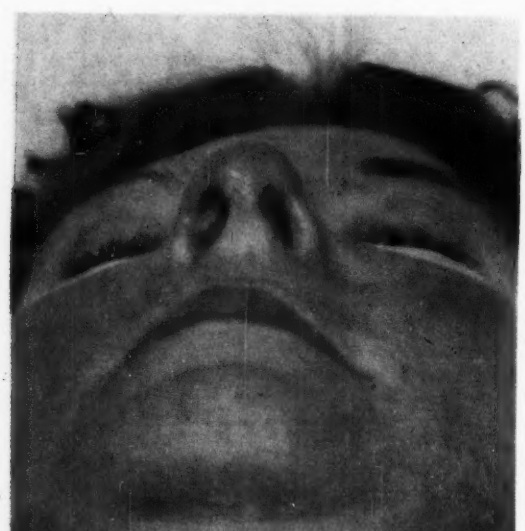


FIG. 337.—Demonstrating the nostril margin, and its lining and support of a wide open character.

out a portion of the skin and cartilage of the concha in one piece and making a free graft of this under that part of the forehead destined to make the new nostril. The free chondro-cutaneous graft succeeded *in toto* and the new nostril margin, when the nose was made, has proved to be delicate in shape and voluminous as regards its opening (*Fig.* 333). In making such a free graft a larger piece of skin was cut than of cartilage, and it is a moot point whether the blood-supply into the graft came through this fringe of skin to the middle of the patch of skin, or whether some blood-supply or nourishment penetrated the cartilage, and so reached the adherent skin on its concave surface. That such a combined graft will survive is an interesting fact, and one which may lead to its use in other regions in which the thin epithelium backed by suitable cartilage support is required; for instance, it should make the basis of a very excellent eyelid, when the globe is not present and one of the lids has been destroyed. It might also be used in stenosis of the larynx and trachea, and in collapsed alæ nasi (*Fig.* 334).

The notes of the case treated are as follows :—

Mrs. L. O., aged 33 years, had her nose bitten off by a dog on Aug. 8, 1941. (*Fig.* 335.)

First operation (Aug. 14), implantation of chondro-cutaneous graft in forehead.

Second operation (Sept. 17), forehead flap with new-made ala brought into position on nose.

Third operation (Oct. 3), return of forehead flap pedicle.

Fourth operation (Jan. 8, 1942), nasal trimming. (*Figs.* 336, 337.)

SUMMARY

A new type of free graft is described in which skin and ear cartilage are grafted in one piece. Its uses are limited.

I wish to express my acknowledgements to Dr. Gabarro for his diagrams of this case, and to Mr. P. G. Hennell for the colour photographs. I wish to thank the D. G., E.M.S., for permission to publish this case. I am also indebted to Mr. J. B. Cuthbert for permission to publish *Fig.* 334.

REFERENCE

IVANISSEVICH, O., *Surg., Gynecol. and Obst.*, 1940, **71**, 187.

REPAIR OF LIMB WOUNDS BY THE USE OF DIRECT SKIN-FLAPS*

BY MAJOR D. O. BROWN, R.A.M.C.

FUNCTIONAL disability following severe limb injuries is very often, in great measure, due to skin loss. Replacement of the skin loss is an essential part of the treatment of such cases. Without such replacement orthopædic correction and physiotherapy can achieve only mediocre results.

It is a cardinal postulate of plastic surgery that skin transferred for replacement of losses should approach as nearly as possible to the skin lost. Consequently the ideal method of replacement must always remain the use of local flaps. However, the application of local flaps in the repair of severe limb wounds is limited. Usually there is insufficient tissue available. Further, owing to the relative poorness of the blood-supply, as compared with the face, it is often unsafe to use adequate rotation flaps. Nutrition of the flaps demands such a broad base that the requisite rotation is impracticable. Transposition flaps, the Z-plasty design, have a wide application in the correction of linear contractures about the flexor aspects of joints. The method has been discussed and illustrated extensively in surgical literature.[1–3]

Nevertheless, where loss has been extensive, it is commonly found that no method of repair involving the use of local flaps alone will provide adequate correction. Transference of skin from a distance is then required. In certain cases local flaps can be made to cover an area of great functional significance, and the resulting secondary defect nearby covered by the use of a free graft. In other cases an entirely satisfactory functional and cosmetic result can be obtained by the use of a free graft alone. However, particularly where the function of underlying structures is of primary concern, the use of full-thickness skin with some underlying fat is essential. In many groups of cases the use of a free graft will give at best an indifferent result. In other cases, for purely mechanical reasons it will result in partial or total loss.

For its survival a free graft requires adequate blood-supply from the base tissues. In the lower limbs, particularly at the site of an old extensive tissue loss, with dense fibrosis, it is often not practicable to provide conditions of adequate blood-supply. Free grafts are not applicable over exposed bone, cartilage, or tendon. Moreover, contraction of a free graft is constant and may involve reduction to one-half of the original

* The material on which this paper is largely founded is collected from experiences while serving as plastic surgeon to one of the Plastic and Jaw Injury Centres of the Emergency Medical Scheme. I am much indebted to this service for the opportunities afforded and for the permission to quote these cases.

size. Such contraction of a graft used to cover a defect over a joint will result naturally in recurrence of deformity and loss of function. Further, subsequent operations on nerve-trunks transference of a full-thickness flap from a distance has three possible disadvantages: It requires at least two operations; it involves for the patient much more of inconvenience and sometimes acute

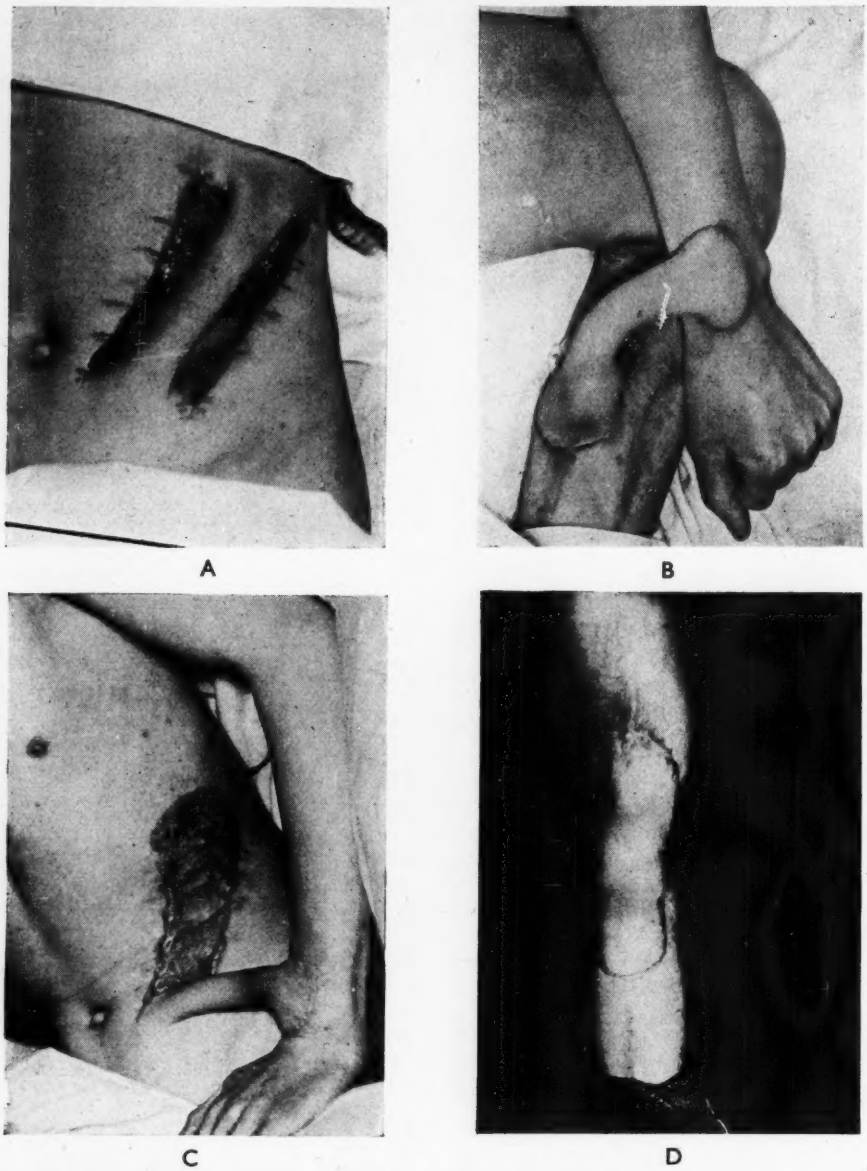


FIG. 338.—Photographs illustrating the use of an abdominal tubed pedicle flap for the repair of an unhealed wound of several months' duration in the popliteal region. This case was regarded as unsuitable for repair by the direct-flap method. (Case of Mr. J. B. Cuthbert.)

or bone structures cannot be embarked upon with any freedom or great hope of success, if the incision lies in the grafted area. Lastly, the appearance of the grafted area is usually, and will remain, indifferent. This constitutes a serious objection to the use of a free graft for the repair of skin losses in, for example, the forearm of a woman.

On the other hand, as compared with the use of a free graft, any method which involves the discomfort; it may produce a considerable secondary defect.

However, in view of the vastly better functional and cosmetic results obtainable, the only objection which merits any consideration is that of discomfort. It is often stated authoritatively that cross-legged flaps involve acrobatic positions and intolerable discomfort. In our recent experience this has not been the case. I believe that the use of a new form of plaster fixation which we have

introduced at one of the centres in the past year has greatly facilitated the nursing of these cases, and has made them much more comfortable by the elimination of voluntary muscular effort towards the maintenance of acrobatic positions. The method of use and application of the plaster will be described later.

Two methods are available for the transference of full-thickness skin with underlying fat from a distant source :—

1. Transfer via the wrist or forearm, usually in the form of an abdominal tubed pedicle, as described by Sir Harold Gillies, and widely used.[4]

2. Direct flap transference, achieved by bringing the recipient area into contiguity with the donor area, and attaining partial attachment thereto, the attachment being completed at a second operation when the base of the donor flap is divided.[5]

The tubed pedicle method, while almost universally applicable, involves the use of at least four operations over a period of at least three months. Consequently, where it is mechanically possible, the method of repair by the use of the direct flap is preferable. Tubed pedicle repair of limb defects is reserved for the few cases in which the direct flap method is not available for mechanical or other reasons (*Fig.* 338).

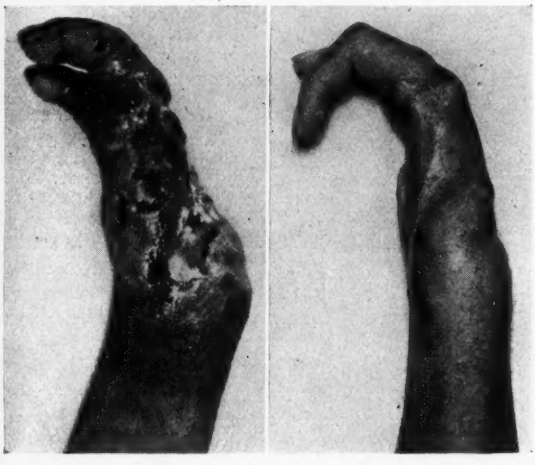


FIG. 339.—Severe hand injury treated by early excision of dead tissue and application of free graft. The immediate application of an abdominal flap would have given a better appearance and a bed of sound tissue favouring any later plastic or orthopædic procedures.

APPLICATIONS OF THE DIRECT FLAP METHOD

1. Recent injury with extensive skin loss in regions of great functional significance. Thus, such wounds of the hand or forearm or elbow region should be covered with an abdominal flap as soon as possible. *Fig.* 339 shows a hand, half of which was avulsed in a machine accident. The man was admitted to hospital ten days later. After three days all the dead tissue was excised and the extensive raw area was covered with a thin razor graft. The graft was almost entirely successful and healing was quickly completed. The function in the remaining fingers is still poor, in spite of intensive physiotherapy. Such a case would have been better treated by the immediate application of a direct abdominal flap.

FIG. 340.—A, Old compound fracture of forearm with skin loss and contracture, and ulnar nerve paralysis. All scar tissue excised. The strap of skin in the middle of the wound was moved towards the ulnar side where it was sutured. B, The remaining defect was covered by a direct abdominal flap. Contracture relieved.

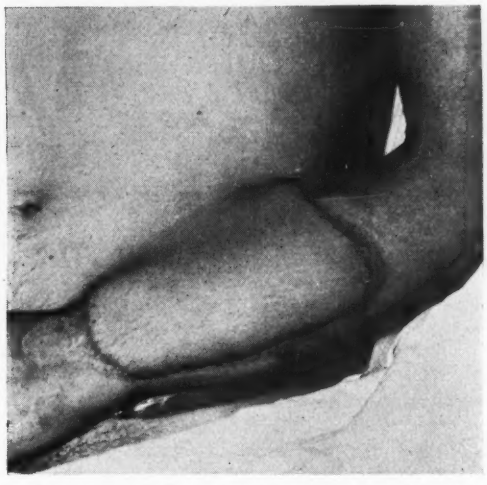


FIG. 341.—For the ulnar border the base of the flap is normally inferior. For the radial border the base of the flap is superiorly placed. (Case of Mr. J. B. Cuthbert.)

2. Old unhealed wounds, or wounds healed with tissue loss and contracture, in regions of great functional significance, or overlying bone or tendons, or over regions bearing weight. Hence old wounds commonly requiring the use of a direct flap repair are :—

a. Forearm injuries, particularly the compound fracture, with extensive tissue loss on the volar surface, and often ulnar nerve paralysis. *Figs.* 340–342 illustrate this type of case.

b. Injuries about the elbow-joint, notably those with tissue loss on the volar surface and flexion contracture. Less commonly injuries requiring skin replacement on the dorsal aspect over the olecranon.

c. Hand and finger losses sometimes (*Fig*. 343).

d. Popliteal fossa losses (*Fig*. 344).

e. Foot and heel losses (*Fig*. 345).

TYPES OF FLAP COMMONLY USED

In the main, losses of the skin of the hand, forearm, and elbow are replaced from the skin of the abdominal wall. Flaps may be cut with the attached base upwards or downwards, or less commonly the double-ended strap flap is used.

Losses of the skin of the lower limb are dealt with by the crossed-leg method, with its almost unlimited variety of design.

Occasionally less usual procedures may be desirable, as, for example, the attachment of a finger to the chest wall or thigh.

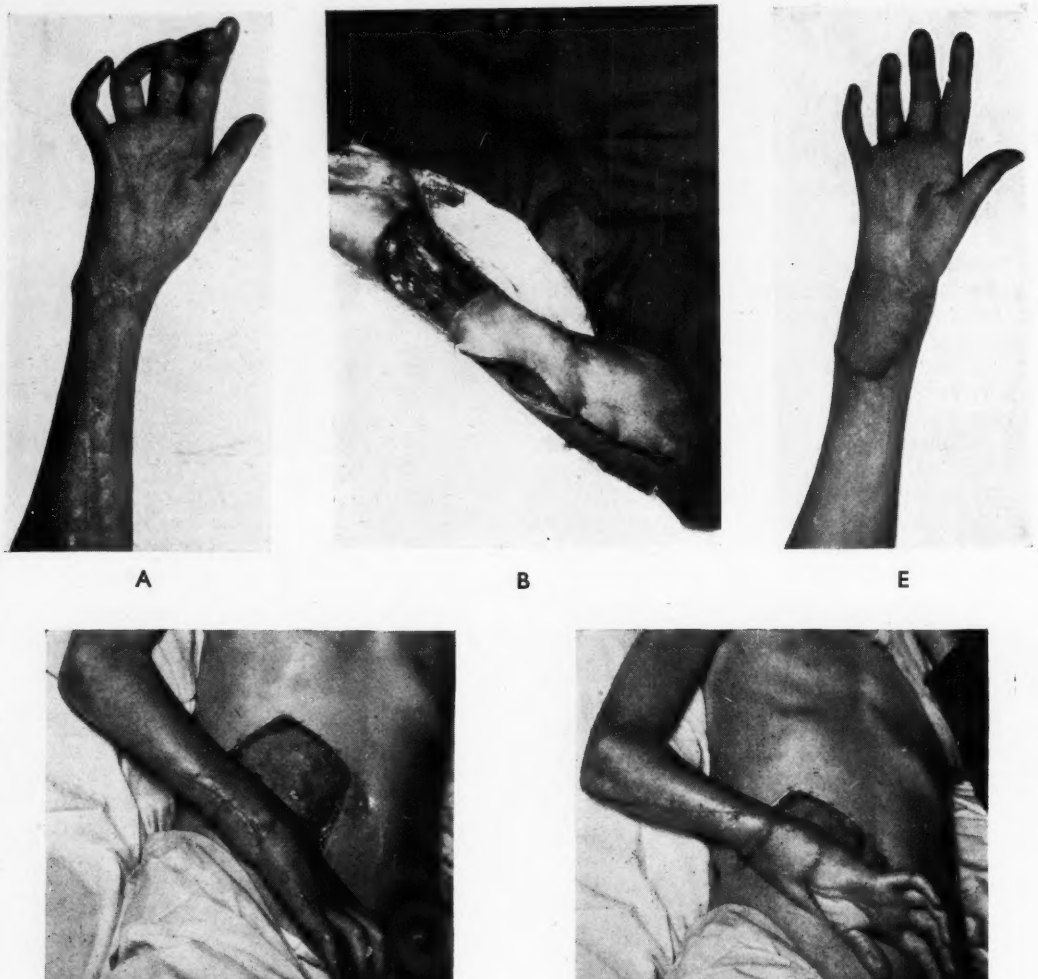


FIG. 342.—A, Old compound fracture of forearm with ulnar nerve paralysis, gross skin loss, and flexion of wrist; B, Photograph taken at operation to show extensive procedure required to establish correctly the defect; C, Direct abdominal flap to wrist; D, During healing of abdominal flap, lowering of the forearm kinks the base of the flap, but at the same time wraps the flap round the arm; E, Result of operation.

TECHNIQUE

Design and Planning.—The procedure for design has been described and illustrated by Gillies[4] and others, and is of the utmost importance. Inaccuracy of design will lead inevitably to tension in the flap, or alternatively to attempts to avoid tension by cutting the basal bridge unduly long, thereby endangering the life of the flap. In either event viability is jeopardized and total loss may result. Planning is done with jaconet, patiently and carefully, and with adequate assistance. Usually the first pattern is made with the patient in bed, and the general operative procedure is decided upon. On the day prior to operation the patient is taken to the operating theatre and

placed in the position that he will occupy on the operating table. The plan is reviewed, and, perhaps, is altered radically, for sometimes a

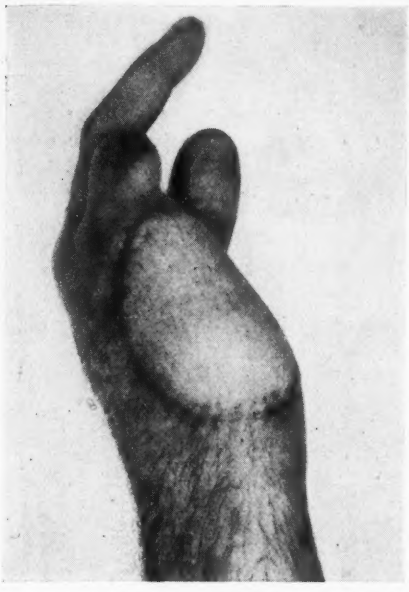


FIG. 343.—Partial loss of hand, dense scar tissue, imperfect healing, functional disability, and pain. Result of repair by direct abdominal flap.

design which appears satisfactory with the patient hunched up in bed appears quite impracticable when he is placed on the operating table.

Provision for Post-operative Fixation.—Fixation after operation is of the first importance. In the case of abdomen-to-forearm flaps, elastoplast provides the most convenient and best means of fixation. It can be easily and quickly applied, and allows all the fixation required. Further, it is advantageous to be able to alter the relations of the forearm and abdomen after a few days. At this time the viability of the flap is well established, and the base can safely be kinked back to a quite alarming extent in order to, as it were, wrap the flap round the arm closely, as far as and beyond what will be the line of final attachment (*Fig.* 342, D).

In the case of crossed-leg flaps, however, I believe that plaster should almost always be used. Formerly it was used and for the most part discarded on account of the difficulties of its application after operation, and the great risk of localized pressure necrosis and limb constriction associated with its use.

To overcome these objections we have adopted a new technique. *Fig.* 345, B illustrates the first case on which the method was used.

On the day prior to operation, after the last pre-operative plan has been made, the patient is placed in the position which he will occupy after operation. Three separate sections of plaster are then applied, for example, round both thighs and one leg. The legs should be washed thoroughly with soap and water beforehand, but not shaved, so that the non-padded casts will adhere to skin and hairs. Change of posture is avoided as far as possible during drying of the plaster.

At operation twenty-four hours later the plaster is dry and firm. All that is necessary after the operation is completed is that the three sections be joined by a triangle of stout plaster rope, while the limbs are held in the required position by an assistant. This can be done in a few minutes, and with minimal contamination of the wound. The slight contamination that does occur is not of great importance. It is far more important that the flap should be exposed till the fixation is completed. Only then can the surgeon be quite certain that the posture is right. After a few minutes to allow the plaster rope to harden, the patient can be bundled into bed with scant ceremony, the two legs moving together.

The plaster design will vary with the type of case; the principle of application remains the same.

There is one outstanding objection to the preliminary application of plaster. When the upper parts of both thighs are enclosed, there are difficulties in obtaining a large razor graft to cover the donor site. However, although desirable, it is not essential that this area be grafted at the first stage of operation. The alternative is to keep it free of serious infection and to apply a graft to the area, then greatly reduced in size, at the second stage.

It is often advisable to remove one section of the plaster after about seven days, and the remainder usually after fourteen days. In the case illustrated in *Fig.* 345, B the plaster was not removed till the time of final attachment. The base of the flap was thick and œdematous. Although its nutrition appeared excellent, some marginal necrosis about the final attachment was evident after a few days. Although the loss was small, it added many weeks to the time required for final stable healing. Since we have paid more attention to stretching and pulling about of the flap, thereby reducing lymph stasis and œdema, marginal loss has not been evident.

Operative Procedure.—Transference of the skin by the direct-flap method requires two operations with an interval of from three to five weeks. The order of procedure is :—

First Operation :—
- *a.* Establishment of the defect.
- *b.* Final designing.
- *c.* Cutting of skin-flap.
- *d.* Sewing in of skin-flap.
- *e.* Grafting of secondary defect, if required.
- *f.* Fixation.

Second Operation :—
- *a.* Division of flap.
- *b.* Sewing in of base.
- *c.* Repair of secondary defect.

Establishment of the defect involves wide excision of the wound or scar tissue, so that

normal skin is reached all round. The extent to which removal of deep scar tissue is proceeded with is variable. The counsel of perfection is to remove all of it. Usually this is impracticable or actually unsafe, and a compromise must be arrived at. Actually, it would seem that after the application of a skin-flap the greatly improved blood-supply and function of the part results in considerable resolution of remaining deep scar tissue.

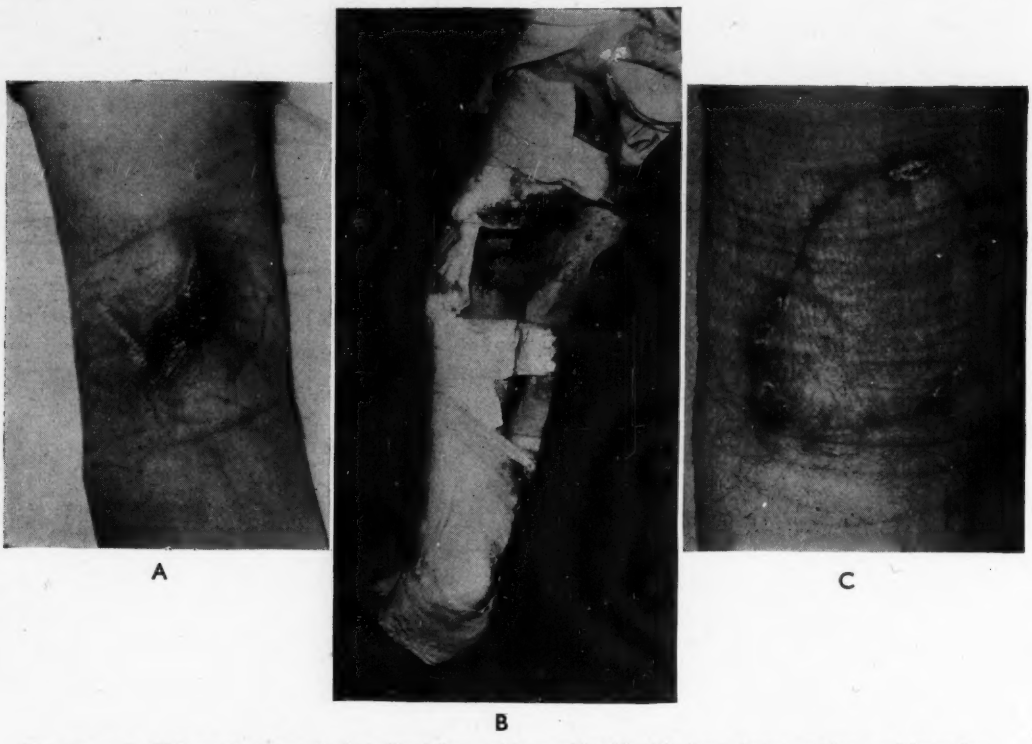


FIG. 344.—A, Old gunshot wound of popliteal fossa with considerable skin loss, dense scarring, and imperfect healing; B, Direct flap from opposite thigh, note plaster fixation; C, Early result.

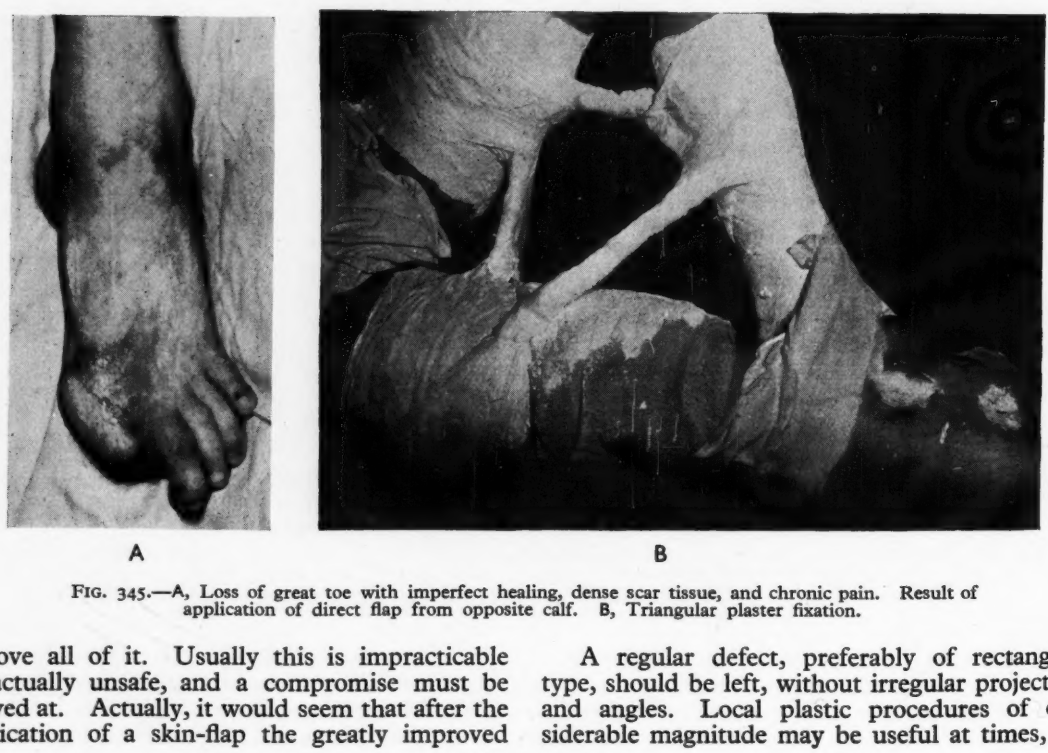


FIG. 345.—A, Loss of great toe with imperfect healing, dense scar tissue, and chronic pain. Result of application of direct flap from opposite calf. B, Triangular plaster fixation.

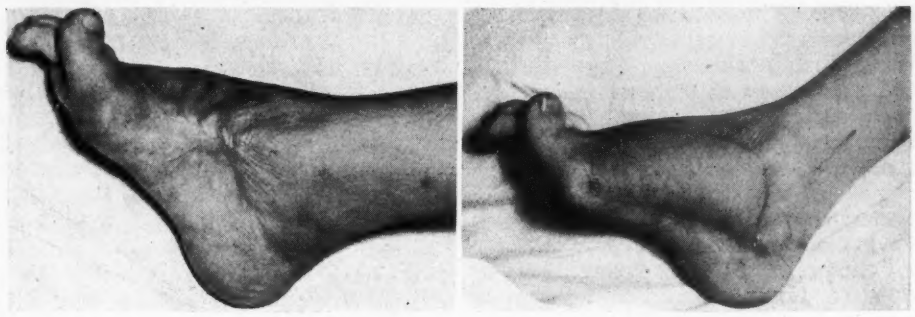
A regular defect, preferably of rectangular type, should be left, without irregular projections and angles. Local plastic procedures of considerable magnitude may be useful at times, but

must be used with caution. *Fig.* 342, B shows wide reopening of an old forearm scar, with lifting of the flap, in order to allow the skin of the forearm to resume its original and correct position, leaving a large rectangular wrist defect. Quite often it will be found that the pre-operative estimate of the size and shape of the defect has been inaccurate, so that at this stage of procedure the patterns are compared with the defect and modified, or, if necessary, entirely replaced.

be avoided. Here everything depends on the accuracy of planning. A relatively small error in the design of a difficult oblique flap may lead to a surgical morass.

Careful suturing with avoidance of inturned edges is essential. The use of a few vertical mattress sutures is usually advisable.

Where there is any likelihood of infection with hæmolytic streptococci, sulphonamide powder is applied freely beneath the flap. Further,



A B

FIG. 346.—A, Extensive loss of medial aspect of foot of child with deformity and interference of growth. Excision of scar tissue involved free exposure of the bony structure of the foot, a base unsuitable for a free graft. B, Restoration by direct flap from opposite thigh. *Note.*—It was considered inadvisable to treat the great toe defect at this stage.

The flap should be cut with bold straight incisions, and the undermining done with sweeping knife cuts, preserving the same thickness throughout. Particularly should "tailing off" of the edges be avoided. The thickness of the flap will depend mainly upon the site and condition of the recipient area. Thinly cut flaps will in general give better cosmetic results, but undue thinness may endanger viability. It is vital to retain undamaged the cutaneous vessels running between the dermis and fat. The safest flap is that cut straight down to deep fascia and lifted at the fascial level. In the case of lower limb repairs, and in other instances in a spare patient, such a deeply cut flap is usually adequate. In the case of fat subjects, and for use in repair of hand and forearm losses, the use of a thinner flap will be required.

It is essential that the flap be handled carefully. Absolute hæmostasis must be attained with forceps and gentle pressure and usually a few ligatures of the finest catgut. The skin-flap is then brought into contiguity with the prepared raw area and a few key sutures inserted. In most cases the flap is then sewn in along three sides of a rectangular figure, or the equivalent in the case of an oval or irregular design. It is our usual practice to score the base of the flap with a scalpel along the proposed line of later division and final attachment. Maximum safety is attained when this is a straight line joining the limits of primary peripheral attachment. Usually about 2·5 cm. of unattached bridge is required at the base. If tension is evident, either the design is faulty, or insufficient bridge has been allowed. The bridge should be as short as possible, but tension must

sulphonamide or its equivalent may be given by mouth, or by injection, for a few days.

Drainage with corrugated rubber or twisted silkworm gut may be advisable for a few days.

Before the final fixation is applied a razor graft is cut if thought desirable and applied to the raw surface remaining.

It is a counsel of perfection to provide skin covering for all raw surfaces. However, in actual practice it is not always done. If a graft is applied the greatest care must be taken to ensure that pressure fixation of the graft in no way interferes with the circulation of the base of the flap. The success of the graft is entirely subsidiary to that of the flap. In most cases the graft can be applied on tulle gras, and covered with a limited quantity of flavine paraffin wool and gauze, fixation being completed with one or more strips of wide elastoplast.

Final adjustment of the limb position is now made, with special care that there is no shift producing tension in the base of the flap. The flap is covered with a piece of tulle gras, and fixation completed by uniting the plaster units with plaster rope. A light dressing can be conveniently kept in place by the use of a many-tailed bandage.

The flap should be examined within a few hours of operation and watched closely afterwards. In the case shown in *Fig.* 344 a massive hæmatoma developed under the flap twenty-four hours after operation. The patient was taken to the theatre and most of the sutures were removed. After thorough irrigation and removal of the clot, the flap was resutured. The final result covering the difficult popliteal area is excellent. This

man sustained his injury at Dunkirk and came to us at an E.M.S. centre still unhealed after more than twelve months of treatment with plaster and dressings of various types.

Massage can be commenced, as a rule, a few days after operation. Sutures are removed in from three to five days. Plaster fixation, if used, is entirely removed by the end of the second week. Increasing freedom of movement is encouraged, and massage is very valuable at this stage.

Bacterial cultures are advisable prior to the division of the flap. The presence in granulating areas of hæmolytic streptococci or *B. pyocyaneus* will sometimes justify delay to allow further cleansing and application of sulphonamide powder. We were fortunate in having the services of Colonel Colebrook, whose advice as to when it was safe to proceed, was often of great value.[6,7] In the absence of bacteriological control, the condition of the granulation tissue proves a sound guide. Low flat pink granulations with minimal exudate deny the presence of significant infection.

Provided that the mechanical and bacteriological factors have been attended to, and the primary design is correct, the second stage presents no difficulty. Guided by the original score mark and the actual line of the remaining free edge of the defect, a knife cut divides the base of the flap along the correct line. Granulation tissue and young fibrous tissue are removed and suture is completed after adequate undermining.

The donor site is closed by excision of granulation tissue and fibrotic edges, and suture with or without further grafting. Sometimes following the cutting of an abdominal flap of moderate size the whole area can be closed by direct suture after wide undermining on the fascial plane. I have an impression, however, that this procedure is unwise as a rule, as excessive bleeding and later hæmatoma formation is likely to occur, even when time and care is expended on hæmostasis. Finally, a light pressure dressing is applied.

It is a sound procedure, as a general rule, to manipulate each joint, the movement of which has been limited by the fixation, through its full range of movement while the patient is still anæsthetized. If this is done and massage commenced on the day following, there need be no fear of the subsequent limitation which is so often mentioned as a serious objection to the use of crossed-leg flaps.

Complications.—Significant losses due to infection are quite uncommon. Hæmatoma formation under a flap may lead to serious loss unless dealt with promptly.

Nutritional losses may be due to inadequacy of design, or to faulty technique. On the other hand, the most experienced surgeon may, with full knowledge of the risks involved, prefer to ' sail close to the wind ', in an attempt to achieve functional and cosmetic perfection. Occasionally, then, it is inevitable that significant losses will occur.

Imperfect union with delayed healing, but without material tissue loss, is not uncommon. Beyond the fact that this may lead to a thick scar requiring minor operation for excision later, it is not important. Losses of tissue, when they do occur, involve, however, considerable delay in healing. Excision of the granulating area and direct suture will almost invariably result in tension and failure, only increasing the size of the defect. Probably the best procedure is to use pressure dressings and temporize. If healing is unduly delayed, at such time as will allow the blood-supply of the flap to be well established, the raw area may be covered by rotation advancement from the main flap if there is any redundancy. Alternatively, a flap may be designed from the adjoining host tissue. In the latter event a residual defect nearby may require a small free graft.

The patient must be made responsible for attention to two precautions following operation. In the case of lower-limb flaps a firm crêpe bandage should be worn for several weeks. The régime is that applicable to a recently healed varicose ulcer. Further he must understand that, owing to the temporary loss of nerve-supply, such flaps are unduly susceptible to injury, and must be protected till well established, particularly from burns. Even mild sunburn may have serious consequences.

SUMMARY

The principles underlying the repair of limb wounds by the use of direct skin-flaps are described.

A new technique for the application of plaster fixation in crossed-legged flaps is described.

The importance of accurate designing is stressed.

Significant details of surgical technique are discussed.

In conclusion, I should like to offer my sincere thanks to Sir Harold Gillies, whose teaching and advice have constantly guided my thought and work, and provided the stimulus without which this paper would not have been written. I am also greatly indebted to Mr. A. H. McIndoe and Mr. Rainsford Mowlem.

REFERENCES

[1] MacCollum, *Amer. Jour. Surg.*, 1938, **39**, 275.
[2] Davis, J. S., and Kitlowski, *Ann. of Surg.*, 1939, **109**, 1001.
[3] Jones, H. T., *Surg. Gynecol. and Obst.*, 1934, **58**, 178.
[4] Gillies, H. D., *Amer. Jour. Surg.*, 1939, **43**, 201.
[5] Gillies, H. D., *Brit. Med. Jour.*, 1932, **2**, 1008.
[6] Colebrook, L., *Bull. War Med.*, 1941, **11**, 73.
[7] Colebrook, L., and Francis, A. E., *Jour. Pathol. and Bacteriol.*, 1941, **53**, 155.

SCIATICA AND THE MECHANISM OF THE PRODUCTION OF THE CLINICAL SYNDROME IN PROTRUSIONS OF THE LUMBAR INTERVERTEBRAL DISCS

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SCIATICA, or pain along the course and in the distribution of the sciatic nerve, is a symptom which frequently causes patients to seek medical advice. At times the pain is of great severity and results in complete incapacitation. More often the suffering is less acute, but it is frequently prolonged and may restrict the patient's activities for months or years. Moreover, during this period of chronic disability recurring attacks of more severe pain frequently occur. Until recent years the treatment of this large group of patients had often proved unsatisfactory. This was largely due to lack of a clear conception as to the aetiology of the condition. It has been customary to classify as secondary or symptomatic those cases of sciatica in which the symptom was due to some demonstrable cause—for example, malignant disease in the pelvis—and as primary sciatica the much larger group in which no obvious cause for the symptom could be found. Various aetiological hypotheses have been put forward to explain this large group. The presence of an interstitial sciatic neuritis due to toxins has been perhaps the most widely accepted of these hypotheses, although the evidence for its occurrence has never been convincing.

This lack of certain knowledge as to the aetiology of the majority of sciaticas has led to a wide diversity of treatments. Although for each new form of therapy good results have been claimed, a large proportion of patients continued to suffer, and indeed rest alone produced relief in the majority of cases. Too often with the resumption of activity pain recurred, so that from the economic standpoint treatment by rest was frequently unsatisfactory.

The first step towards being able to offer speedy relief to many of this large group of patients came with the indication by Mixter and Barr in 1934 that low back and sciatic pain were sometimes produced by herniations or ruptures of the lumbar intervertebral discs into the spinal canal. Again in 1935 Mixter and Ayer emphasized the importance of this cause of sciatica. At the time it was considered that such a lesion was a relatively uncommon cause of sciatica and that it was therefore essential to demonstrate the disc protrusion radiographically by means of an intrathecal lipiodol injection. There was reluctance on the part of many to inject this material into the spinal subarachnoid space in any but the most severe cases. This led to the introduction of spinal aerography (Scott and Young, 1937; Reichert, 1937). The procedure allowed of the investigation of a larger group of patients, since if it proved negative a non-absorbable and perhaps injurious material had not been left in the spinal subarachnoid space.

During the last few years the careful clinical study of a large number of patients in whom sciatica was later proved to be due to a protruded intervertebral disc has lead to the recognition of a typical clinical syndrome of this condition. Indeed, it is often possible to localize the level of the affected disc on clinical grounds alone. It is now believed by many that the diagnosis of a protruded lumbar disc based on clinical examination is less likely to be misleading than are the results of investigation of the lumbar canal with lipiodol or oxygen (Bradford and Spurling, 1939; Semmes, 1939; Dandy, 1941; McKenzie and Botterell, 1942). In the thirty consecutive cases of a personal series contrast myelography has not been used, and in every one a protruded disc has been removed at operation. Furthermore, recent experience has modified the earlier views about the incidence of disc protrusions; for if spinal tumour, tuberculous and metastatic malignant disease of the spine, and malignant disease of the pelvis can be excluded, there remains but one common cause of sciatica and that a protrusion of a lumbar intervertebral disc into the spinal canal. This view has been expressed by several authors—among them Pennybacker (1940), Dandy (1941), and McKenzie and Botterell (1942). It is also the personal opinion of the author.

The results of treatment of sciatica by removal of the protruded intervertebral disc have been excellent in a personal series of cases. The published results of large series dealt with in the United States have been on the whole very satisfactory. Here, then, at last, is a method of treatment which will relieve a very large number of patients suffering from sciatica. The outstanding problem now is that of the selection of the cases which require treatment by operation. Obviously it will not be indicated in an acute attack of sciatic pain which quickly clears up with rest. Neither will recurrent attacks of mild pain require operation. In all other cases in which the diagnosis of a protruded intervertebral disc has been made, in which the pain is sufficiently severe to indicate operative treatment, and in which there is no contra-indication to it, operation must be seriously considered.

The purpose of this paper is twofold. First, the typical syndrome of the lower lumbar intervertebral

disc protrusions will be described, since it is on this that the clinical diagnosis of the condition depends; secondly, since the current explanations of the mechanism by which a protruded lumbar disc produces its clinical syndrome are considered inadequate, an alternative hypothesis which is believed to accord better with the observed facts will be put forward.

The paper is based upon a clinical and an anatomical study. The clinical observations were made on a personal series of more than 75 cases of protrusion of the lumbar intervertebral discs in which the lesion has been displayed at operation. In this group an attempt has been made to correllate the history and physical signs with the operative findings. In addition the cauda equina has been examined in five cadavers. Its anatomy has been studied and special attention has been paid to the effects of movement of the spine and lower limbs upon the nerve-roots of which it is composed.

THE CLINICAL PICTURE IN PROTRUSIONS OF LOWER LUMBAR DISCS

(Only the discs between the 4th and 5th lumbar vertebræ and the 5th lumbar vertebra and the sacrum are considered.)

A. Severe cauda equina lesion.

B. The typical case.

History:—

1. Distribution and type of pain.
2. Factors which induce variations in severity of pain.
3. Intermittency of symptoms.
4. Paræsthesiæ.
5. Trauma.

Examination:—

1. Age and sex of patients.
2. Mental state.
3. The spine.
4. Straight leg raising.
5. Sciatic tenderness.
6. Motor disturbance.
7. Sensory disturbance.
8. Reflex disturbance.
9. Radiography.
10. Lumbar puncture.

The features of the clinical syndrome to which reference will be made are listed above. From this it will be seen that two entirely different pictures may follow protrusion of a lumbar disc. Very rarely—but one case in the present series—there is evidence of a severe cauda equina lesion with paralysis and sensory loss in the distribution of the sacral and perhaps lower lumbar roots and severe disturbance of vesical and rectal control. This dramatic picture is uncommon, and fortunately so, since after complete removal of the disc protrusion recovery may be very long delayed and will perhaps never be complete. Commonly, the picture following a disc protrusion is much less striking, yet a careful history and examination will show it to be none the less characteristic. The features of this second and common type of clinical picture will now be considered in detail.

The History.—

1. *Distribution and Type of Pain.*—The pain usually commences in the lumbosacral region, passes across the buttock, and down the posterior or postero-lateral aspect of the thigh to the popliteal region. Usually it spreads farther downwards along the outer side of the calf to the ankle, from which it may radiate forwards along the dorsum of the foot to the toes or across the heel into the sole of the foot. Occasionally there is no backache associated with the sciatic pain, and at other times the lower limb pain may be confined to a part only of the above sciatic distribution, for example, the lateral portion of the calf. No patient in this series of verified protrusions of the lumbar discs had low back pain without sciatic pain.

As regards the type of pain, this varies considerably. At times it is intensely severe and stabbing, the patient being afraid to make any movement. Often the pain is a constant dull aching and frequently the patient describes it as "drawing" or "something which draws the limb upwards".

2. *Factors which induce Variations in the Severity of the Pain.*—Very frequently it will be noticed that there are factors which relieve or aggravate the sciatica. It may be stated that any form of exercise, even walking a few hundred yards, markedly aggravates the condition. Coughing, straining, and other forms of violent effort often produce a like result. Occasionally it will be stated that not only does bending forward increase the pain, but so also does lateral flexion of the lumbar spine, especially perhaps to one side. Strangely, too, at times flexion of the neck increases the pain.

Most patients have found that rest relieves them, although it often happens that the pain wakes them at night and relief may then be gained by varying the posture in bed or even getting up and walking about for a short period. An attempt will be made to explain this apparent anomaly later. Attention to the posture of the lower limbs may also bring relief—the affected leg being flexed at the knee- and hip-joints and the sound limb extended at these joints. One patient noticed that after walking a few hundred yards his pain became so severe that he had to stand. He found that by raising the arm on the painful side high above his head his pain was quickly relieved and he was able to walk onwards.

3. *Intermittency of Symptoms.*—In a proportion of patients there will be a history of "a weak back", with attacks of lumbago at intervals for several years before the patient is first seen. Frequently associated with this lumbago there will have been attacks of sciatica. This will often occur in one limb only, but sometimes the two limbs may be affected alternately or even together. It is clear therefore that sciatic pain due to a

protruded intervertebral disc may completely subside or at least greatly diminish for a varying period, after which the symptoms reappear, sometimes in a more intense form.

Further it is strange to find that patients in this group will sometimes have noticed that their pain commenced after a period of exposure in a cold, damp atmosphere, and they will also have noticed that their symptoms are aggravated by such climatic conditions.

4. *Paræsthesiæ.*—Subjective sensory disturbance—apart from pain—is an extremely common occurrence in this group of patients. Tingling, pins and needles, and numbness may occur alone or together. They may be felt in the whole of the painful area, but more usually are confined to a part of it—especially the foot, and the distal part of the leg. Not infrequently the patient will suffer from frequent muscle cramps—especially in the calf. It is significant that the paræsthesiæ are sometimes produced by the same factors which aggravate the pain—certain movements, and coughing. It suggests at once that both are due to some form of mechanical stimulation of nerve-roots in the lower portion of the spinal canal by activity.

5. *Trauma.*—In more than half the cases there is a history of a definite injury which immediately, or within a short period, precipitated the patient's pain. In the remaining cases the pain has been of more gradual onset and not associated in the patient's mind with any injury. Here it may be that the interval between the injury and the onset of symptoms has been long enough to allow the patient to forget the injury. On the other hand, it must be remembered that the lower lumbar intervertebral discs are subjected to quite severe stresses in the course of ordinary activity. Such activity may thus constitute the trauma. In some cases in the series an attack of sciatica has followed trauma to the lumbar spine and has subsequently cleared up. Then, after an interval, a further trauma has reproduced the pain and the patient has come for treatment and a protruded disc has been removed. Various anatomical factors are probably important in rendering some lumbar spines less fitted to withstand the wear and tear of ordinary life than are other spines.

The Examination.—

1. *Age and Sex of the Patients.*—In the series there have been four men for every woman operated upon—a fact doubtless explained by the greater liability of the male to injury (in its widest sense) in the course of his occupation. The youngest patient submitted to operation was twenty and the oldest sixty-eight, the average age for the series being thirty-five years.

2. *Mental State.*—Several of the patients in this group have shown gross emotional instability on admission to hospital. At times this has been so marked as to lead one to suspect that the sciatica had a neurotic basis. Further examination has led to a diagnosis of a protruded intervertebral disc and the removal of the protrusion has led to a rapid restoration of emotional control. It seems important therefore to stress the fact that prolonged chronic pain may produce considerable alteration in outlook and behaviour.

3. *The Spine.*—It will very commonly be found that there is localized tenderness over the lower lumbar or upper sacral spines. In certain of the cases percussion of the spines in this area will lead to an exacerbation of the sciatic pain, and at times to the development of paræsthesiæ in the areas in which they have previously been felt spontaneously.

A loss of mobility in the lumbar spine frequently is evident. This especially affects flexion, but also lateral mobility—in particular when the lateral flexion is away from the painful side.

In a high proportion of cases some deformity of the lumbar spine is present. Sometimes there is simply a greater or less degree of obliteration of the normal lumbar lordosis; at times this may lead to a slight lumbar kyphosis. In many cases there is a lateral tilt in addition. Most frequently this lumbar scoliosis has its convexity directed towards the side of the painful extremity, though occasionally the tilt is in the reverse direction. In a proportion of cases the scoliosis is most striking in that it alternates—the patient's lumbar scoliosis being convex to one side at one time and in the reverse direction at another time. Frequently such patients have learned to alternate their scoliosis at will. Finally, it should be pointed out that even when there is no lateral lumbar tilt when the patient stands erect, a tilt towards the painful side will often become obvious as the spine is flexed forwards.

4. *Straight Leg Raising.*—The importance of this test—often referred to as Lasègue's sign—is widely recognized. Certain features of the test which have received little attention in the literature will be referred to, and a modification of the usual test which has been found to be of value will be described.

The test is carried out in the following manner and is thus in three parts; First, with the patient lying flat and the head supported on a low pillow only, the sound limb is flexed at the hip, maintaining extension of the knee. At a degree of flexion which varies with the severity of the patient's symptoms pain occurs. At times this pain is a tightness in the lumbar region or in the posterior thigh of the flexed limb, but frequently flexion of the sound limb produces an exacerbation of the sciatic pain in the opposite limb. The angle of hip flexion at which pain occurs is recorded. Secondly, the test is carried out on the affected limb—usually with the production of an increase in the patient's sciatic pain in this limb at an angle of flexion considerably less than that permitted on the sound side. This angle is also noted. The third step in the test is the modification which has been mentioned above: with the patient in the same position both legs are flexed simultaneously. It will frequently be found that the angle of flexion permitted is

considerably greater than that allowed when the affected limb is flexed alone; indeed sometimes it is greater than is permitted by either limb flexed separately. Now, having flexed both straight legs to an angle just short of that which produces pain, the sound limb is lowered to the bed and there results a marked exacerbation of the sciatic pain, sometimes associated with paræsthesiæ.

Finally, there remains another point of interest in connexion with this test. It has been stated that the test should be carried out with the patient flat and the head supported by a low pillow only. This is because flexion of the neck reduces the degree of straight leg raising which is possible without pain. If the leg is flexed to an angle just short of that necessary to cause pain, flexion of the neck will produce the same exacerbation of the sciatic pain as would follow further hip flexion through a few degrees.

Like many other features of the clinical syndrome, the phenomena of the straight leg raising test and its modification have an important bearing on the explanation of the whole clinical syndrome of a protruded lumbar disc. This will later receive detailed consideration.

5. *Sciatic Tenderness.*—In many cases tenderness along the course of the sciatic nerve is present. It is frequently most severe over some area such as the buttock, the lower third of the back of the thigh, or the calf, but at times forms a continuous band from buttock to ankle.

In addition to this tenderness along the course of the sciatic nerve, there are often other tender areas. Very frequently the upper glutei on the dorsum ilii are tender, and often what appears to be a thickened area of tender muscle is palpable. These areas have doubtless often been regarded as fibrositic, and the sciatica has been regarded as being referred from them. Any relief obtained by the injection of local anæsthetic into one of these areas can obviously be only of a transitory nature. This has certainly been true in patients of the series who had this treatment before the diagnosis of a protruded disc had been made and the correct treatment instituted.

6. *Motor Disturbance.*—Although actual loss of power in muscle groups is relatively uncommon in cases of protrusion of the lumbar intervertebral discs which show the characteristic syndrome, other evidence of disturbance of motor function is rarely absent. Atrophy, diminution of tone, and sometimes fibrillation are seen in some part of the motor territory of the lower lumbar and upper sacral roots on the affected side. It is unusual for the atrophy and hypotonia to be absent in the glutei; the hamstring group is sometimes affected and frequently the changes are seen in the calf. Sometimes actual paresis or even paralysis is present. It may involve dorsiflexion and eversion of the ankle or plantar flexion and inversion. Occasionally extension and abduction of the hip are affected. It is sometimes difficult to decide whether apparent weakness is a true motor defect or is due to reluctance to move the limb forcibly because of the increased pain which such an effort would call forth.

A number of patients have been seen in which the following history is obtained. Some years previously the patient has had a severe attack of lumbago and sciatica and this was followed by the development of foot-drop. With the occurrence of the paralysis the sciatica ceased. It is believed —though not proven—that in these cases a disc protrusion has occurred. It produces such severe damage in a pair of nerve-roots (anterior and posterior) that complete degeneration results in them. The pain thus ceases and the motor disturbance is perhaps permanent. Not one of these cases has been operated upon so that the proof that the symptoms are due to a disc protrusion is lacking. Operation has not been done since it has been felt that degenerative changes (which had been present for several years) in a nerve would not be likely to be benefited by the removal of the cause which had in the first instance produced the degeneration.

7. *Sensory Disturbance.*—Very commonly careful sensory examination will reveal a sensory defect in the affected limb. The area of hypalgesia and hypæsthesia will most commonly lie within the area of the lateral aspect of the leg and the dorsum and sole of the foot (that is, in the fifth lumbar and first sacral dermatomes). At times the reduction in sensibility will involve the posterior thigh and calf (the second sacral dermatome). There may also be a reduction of postural sensibility in the lateral toes of the affected foot and vibration sense may be reduced on the lateral malleolus of the painful limb.

8. *Reflex Disturbance.*—In cases of sciatica the knee-jerks are usually brisk—that on the affected side being at times the brisker. Frequently the ankle-jerk will be diminished or absent on this side, though it may be unaffected.

9. *Radiographic Examination.*—It has been suggested that the importance of radiography combined with the injection of contrast media (oxygen or lipiodol) has been overstressed, and it is now believed by many that such measures are rarely, if ever, necessary. However, plain films of the lumbosacral region must always be made, first, to exclude gross bone disease such as metastatic malignant disease, and secondly, because at times a clinical diagnosis of a disc protrusion may gain confirmation from plain films. The affected intervertebral interval appears narrow and there may be lipping of the vertebral margins localized to this level. Narrowing of the lumbosacral disc would be unimportant since there are considerable variations in its width, but the fourth lumbar disc shows a smaller normal range of variation and a pathological change in the disc can be recognized with greater certainty. Thirdly, plain films will show congenital variations in the lumbar spine, such as sacralization of the fifth lumbar vertebra. These must be considered with the clinical picture when clinical localization of the affected disc is being carried out.

10. *Lumbar Puncture* was at first performed in every case, but its value is perhaps not sufficient to merit this. In the common type of protrusion there is no subarachnoid block, so that even if the lumbar puncture is done below the level of the encroaching protrusion the Queckenstedt phenomenon is normal. If a small quantity only of fluid is removed there may be an increase in protein concentration. This is, however, rarely marked and is often absent. Thus, on the whole, lumbar puncture does not give much assistance in the diagnosis of protrusion of a lumbar disc, and in the latter cases in the series it has rarely been performed.

Before passing from the consideration of this clinical syndrome, it should be pointed out that all protrusions of the lumbar intervertebral discs do not produce pain of sciatic distribution. The intervertebral discs between the fourth and fifth lumbar vertebræ and between the fifth lumbar vertebra and the sacrum are by far the most frequent sites of protrusion. Protrusions at these levels give rise to the syndrome described above. Depending upon whether the fourth or fifth lumbar disc is involved, the clinical picture will be slightly different. This has been emphasized by Spurling and Bradford (1939, 1941) and later by McKenzie and Botterell (1942). Thus, when the fourth disc is involved the paræsthesiæ and objective numbness may involve the medial portion of the dorsum of the foot and the ankle-jerk may be unaffected. On the other hand, when the fifth disc protrudes, the sensory disturbance is placed farther laterally on the foot and the ankle-jerk may be diminished or absent. This difference in clinical pictures is due to the fact that a protrusion of the fourth disc largely involves the fifth lumbar root, while a protrusion of the fifth disc especially affects the first sacral root (*see Fig.* 348). It may be difficult, however, to decide on clinical grounds whether the protrusion has occurred at the fourth or the fifth lumbar disc. Occasionally a protrusion occurs at a higher level—for example, at the level of the interval between the third and fourth lumbar vertebræ. Here a typical clinical syndrome may also result—pain along the anterior aspect of the thigh and the antero-medial aspect of the leg. Examination may show wasting and fibrillation of the quadriceps, a reduction of sensation in the fourth or higher lumbar dermatomes, and a diminished or absent knee-jerk. But there is no true sciatic pain and hence these cases have been excluded from the above description of the clinical findings in sciatica due to protrusion of the lumbar intervertebral discs.

THE MECHANISM BY WHICH THE DISC PROTRUSION GIVES RISE TO SYMPTOMS

It has been generally accepted that protrusions of the lumbar intervertebral discs produce their characteristic symptoms and signs by compression of the roots of the cauda equina. Thus Mixter, in the discussion which followed the presentation of his original valuable paper (Mixter and Barr, 1934), stated that a tumour far out to the side of an intervertebral disc could compress nerve-roots as they leave the spinal canal and thus produce root pain. Love (1936, 1940), who has had very great experience of this lesion and who has contributed a great deal to the literature on the subject, subscribes to the view that the protrusion compresses a nerve-root. This conception has frequently been illustrated by diagrammatic figures showing the compression of one of the roots of the cauda equina between the disc protrusion and the related ligamentum flavum. Again, Naffziger, Inman, and Saunders (1938) have described the course of the intraspinal nerves in a sulcus between the ligamentum flavum and intervertebral disc and have pointed out that in this situation they are vulnerable to encroachments by either ligamentous or disc tissue. Spurling and Bradford (1939, 1941) have re-emphasized the relationship of the fifth lumbar and first sacral roots to the last two intervertebral discs—a relationship originally described by Hampton and Robinson (1936). The former authors further make the important statement that it is only nerve-roots compressed near their points of exit from the spinal canal which cause symptoms and signs of localizing value.

It will be seen, therefore, that there is wide acceptance of the view that nerve-root compression is the cause of the characteristic syndrome in the protrusions of the lumbar intervertebral discs. One other factor has recently been suggested as the cause of symptoms. Dandy (1941) has described " concealed intervertebral discs ". According to this author these are too small to produce compression of any of the nerves in the lumbar canal, and he suggests that they produce symptoms by becoming adherent to a nerve-root. Further reference will later be made to this hypothesis.

As will be explained, many of the features of the clinical syndrome described above are not readily explicable on the basis of compression of a root or roots by the protruded disc. Neither is adhesion between disc protrusion and a nerve-root an adequate explanation of the syndrome, since there is frequently no evidence of such adhesion at operation. While, therefore, it is likely that compression, friction, and adhesion play a part in the production of symptoms in many cases, the essential factor is believed to be the stretching of an intraspinal nerve in its extradural portion over or around the mass of protruded disc tissue. The constant state of increased tension which results in this nerve accounts for the persistent pain in its distribution. Movements and postures which increase this tension aggravate the pain, while rest and postures which minimize the degree of stretching relieve it; the spontaneous cure which occurs in so many cases of sciatic pain can be explained on this hypothesis,

as can also the occasional benefit of methods of treatment such as manipulation of the spine and stretching of the sciatic nerve. It is considered that these and other features can be more readily explained on the tension hypothesis than on any other. The evidence upon which this hypothesis is based will now be considered under various headings—embryological, morphological, clinical.

Embryological Considerations.—It is well known that in early fœtal life the spinal medulla extends to the bottom of the spinal canal. After the 30-mm. stage (8 to 9 weeks) the column begins to elongate more rapidly than the spinal medulla, so that the inferior end of the latter, or conus, comes to assume a higher position in the spinal canal. The greater part of this migration takes place in early fœtal life, so that by the twenty-fifth week the conus medullaris has ascended from the second coccygeal to the third lumbar segment —that is, to a position only two segments below its adult level of the first lumbar vertebra. This description of the early development of the spinal medulla is taken from *Gray's Anatomy*. In early fœtal life the roots of the spinal nerves pass horizontally outwards from the cord to their intervertebral foramina and have but a short intraspinal course. As a result of the changing relationships of spinal medulla and spinal column, however, the spinal nerve-roots, and especially those arising from the lower portion of the medulla, become elongated in their intraspinal course; they become drawn out between their upper and lower attachments. It is a remarkable fact that it is the intradural portions of the spinal nerve-roots which elongate. Although the extradural intraspinal nerves alter their direction they do not appear to elongate to an extent greater than would be expected from ordinary growth processes at the period of life under consideration. Thus it would seem that when elongation of the intraspinal roots becomes necessary as a result of the relative shrinkage of the medulla within its canal, this elongation occurs at the expense of the intradural roots. Some factor prevents the elongation of the extradural roots, and this factor is believed to be their strong dural sheath. The dural theca, therefore, does not undergo the same relative shrinkage within the spinal canal as does the medulla, and it remains tethered down in the sacral region, its lower end having ascended only from the coccygeal region to the third sacral vertebra. From these embryological considerations

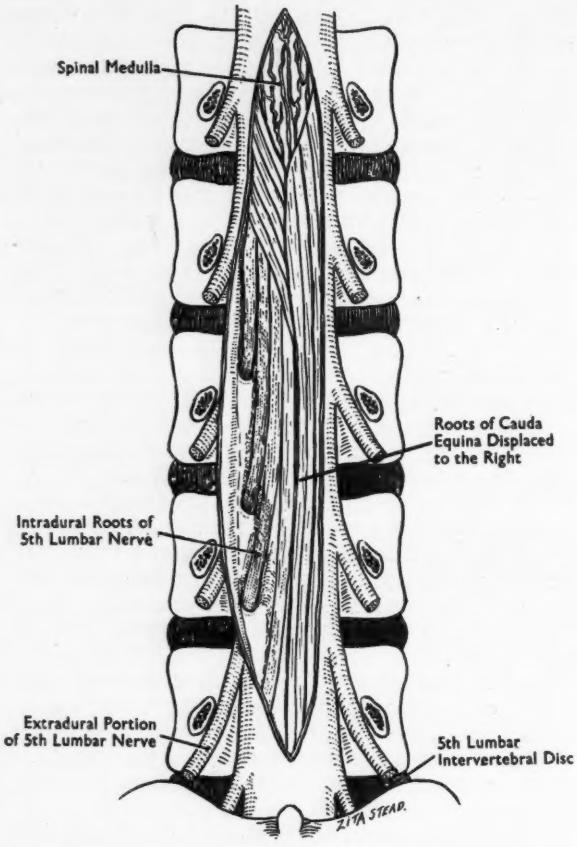
Spinal Medulla
Roots of Cauda Equina Displaced to the Right
Intradural Roots of 5th Lumbar Nerve
Extradural Portion of 5th Lumbar Nerve
5th Lumbar Intervertebral Disc
ZITA STEAD.

FIG. 347.—A diagrammatic drawing of a dissection showing the lumbar portion of the spinal canal and some of its contents. It indicates the long and relatively lax intradural nerve-roots and the short less mobile intraspinal extradural nerves.

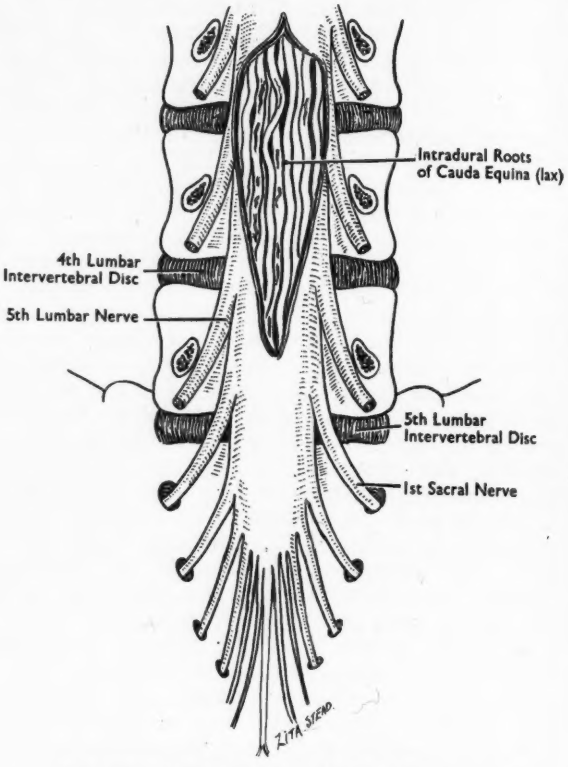

FIG. 348.—A diagrammatic drawing of a dissection to show the dural theca in the lumbosacral region and the extradural intraspinal nerves. The relationship of the fifth lumbar nerve to the fourth lumbar disc and of the first sacral nerve to the fifth lumbar disc is indicated.

it is believed that the extradural intraspinal roots strongly resist any force which tends to elongate or stretch them. The intradural roots, on the other hand, have much less resistance to stretching force and thus permit of elongation.

Morphological Considerations.—An examination of the intradural and extradural portions of the spinal nerve-roots shows that they differ in several respects. The long intradural roots of the cauda equina are relatively lax as they pass from spinal medulla to the dural theca (*Fig.* 347). They can, therefore, be displaced within the theca without showing any tendency to spring back into the position from which they were displaced. The caudal portion of an intradural root is, of course, less mobile than the remainder because of the fixation by the dura. The short extradural intraspinal nerve-root is by comparison much more tense (*Fig.* 348). At its proximal end it is attached to the dural theca. Many observations point to the inelastic nature of the dura, and it may therefore be taken that the upper end of this portion of the extradural root is firmly held. At its lower end this extradural root (which is, of course, a pair of roots—anterior and posterior) is attached beyond the intervertebral foramen by the ramification of its fibres in various branches. Attempts to displace the extradural intraspinal nerve are resisted, and if displaced the structure springs back into its original position when released. The reasons for this difference in the two portions of the nerve must now be considered. The long interval between the upper and lower attachments of the intradural roots, as compared with the short course of the extradural nerve between its fixed

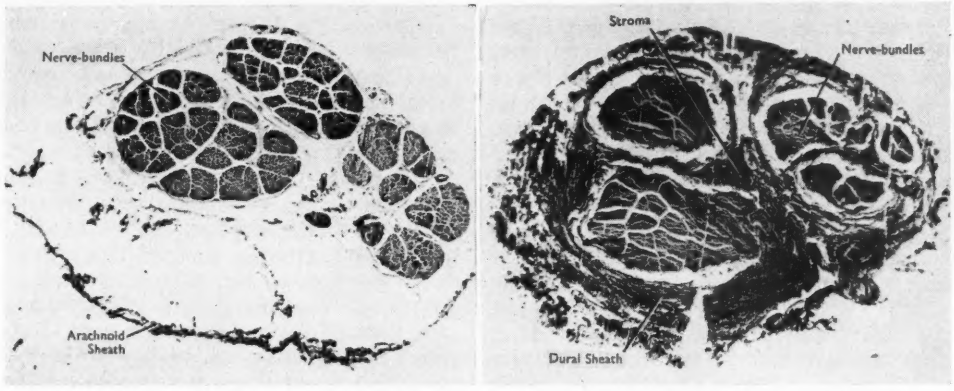

FIG. 349.—Microphotographs of transverse sections of the intradural (left) and extradural (right) portions of the fourth lumbar nerve. Mallory's connective-tissue stain. (× 5).

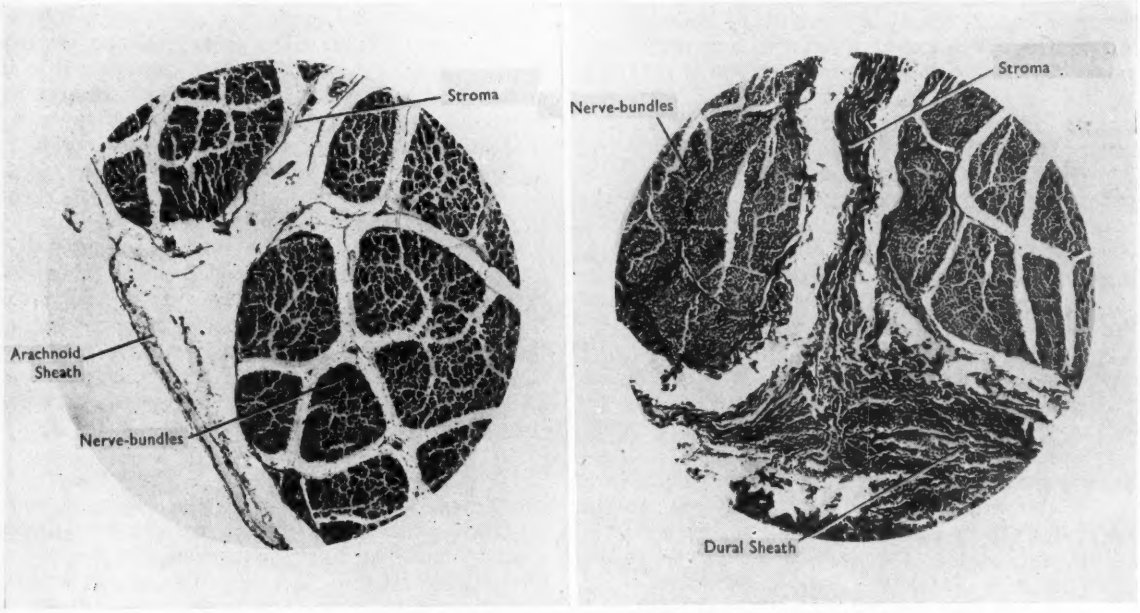

FIG. 350.—Microphotographs of transverse sections of the intradural (left) and extradural (right) portions of the fourth lumbar nerve. Mallory's connective-tissue stain. (× 25.)

attachments is doubtless one reason for this difference in mobility. Histological examination reveals another reason. In *Figs.* 349 and 350 are shown transverse sections of the fourth lumbar nerve-roots (anterior and posterior) immediately before and immediately after they have pierced the dura. In these it will be seen that the intradural roots form a group of nerve-fibres loosely arranged, with little supporting connective tissue and a delicate arachnoid sheath. The extradural portion of the nerve shows the nerve-fibres arranged in more compact bundles with an increased amount of fibrous tissue within these bundles and a very great amount of supporting connective tissue around and between the bundles. This structural addition of fibrous tissue in the extradural roots will confer upon them a rigidity which is absent in the intradural roots. The rigidity in structure and the proximity of the fixed attachments of the extradural nerve-root will explain its resistance to displacement. It is believed that the anatomical differences between the intra- and extradural nerves accounts for the fact that a small tumour related to the fixed tense extradural root will cause severe symptoms, whereas a very much larger intradural tumour may for long cause little disability. Perhaps this structural difference between the intradural and extradural roots also accounts for the inelasticity of the extradural roots as compared with the intradural, which has been suggested as the cause of their differing behaviour in early fœtal life.

The observations made above on the gross anatomical features of the roots of the cauda equina are based on a series of dissections. Certain other observations which were made at the same time will now be described. In each of the five dissections the spines and laminæ of the lumbar vertebra and sacrum were removed. The articular processes were also excised so as to bring the extradural nerves into view. In this way the whole of the cauda equina and the extradural portions of its constituent roots were displayed. *Figs.* 347 and 348, which are semi-diagrammatic, are based on these dissections.

In the dissections the following points—in addition to those already mentioned—were noted. It was obvious that the extradural portions of the spinal nerves were placed far anteriorly in the spinal canal in relationship with the posterior surfaces of the vertebral bodies and intervertebral discs. They were indeed hidden by the bulging dural theca behind them, and they brought to mind guy ropes which held the anterior dura forwards against the vertebral bodies. The posterior dura was relatively lax in a transverse direction, but there was a state of constant longitudinal tension as shown by its gaping when cut transversely. This anterior position of the extradural nerves (*Fig.* 351) suggested that they were unlikely to be compressed against either laminæ or ligamenta flava by the relatively small mass of the common type of intervertebral disc protrusion. It would seem much more probable that the anteriorly placed nerve would by virtue of its fixity and normal tension be subject to a stretch across the protrusion. Further, the position of the nerves in the canal made it appear most unlikely that a hypertrophied ligamentum flavum could ever of itself produce compression of one of them. For the same reason it appeared clear that to do a laminectomy in the presence of a protruded disc in the hope of decompressing the affected nerve would be quite valueless.

The effect of movements of the spine and lower limbs on the normal state of tension existing in the intradural and extradural nerve-roots was next investigated. Before carrying out the experiments rigor mortis was forcibly overcome. Even after this it was usually impossible to prevent flexion of the lumbar spine and hip flexion from occurring together. Lateral flexion of the spine could not be satisfactorily performed either. In spite of these difficulties it is considered that the observations made are important. It was found that flexion of both hips with the knees extended produced an obvious increase in tension in both the intradural and extradural roots of both sides, the dura being drawn slightly downwards as well as forwards on to the anterior wall of the spinal canal. The increase in tension was more obvious in the case of the extradural than in that of the intradural roots—a fact due probably to some of the increase in tension on straight leg raising being transmitted to the dura from the extradural roots so that only a proportion of the stretch reached the intradural roots.

Flexion of one hip only, keeping the knee on this side extended, produced a similar increase of tension in the roots of the corresponding side, and the anterior portion of the dural theca was displaced slightly towards the side of the flexed limb by the movement. Such a movement of the theca towards the flexed limb will produce some increase in tension in the extradural roots of the opposite side, this increase being much less, however, than would result from flexion of the opposite limb itself.

Further, it was noted that when the extradural roots of one side had been rendered tense by flexing the hip with the knee extended, the tension could be immediately relaxed by flexion of the knee on this side. Finally, it was noticed that flexion of the neck produced an upward movement of both spinal cord and dura within the spinal canal, and, of course, therefore, increased the degree of tension in the nerve-roots coursing downwards from the spinal cord.*

From these observations it has been concluded that the degree of tension in the intraspinal roots varies with movements of the spine and limbs. Flexion of the head on the trunk increases the degree of such tension whereas extension diminishes it. Hip flexion with the knee extended

* The bearing of this observation upon the clinical signs of meningeal irritation appears clear and will be discussed in a further communication.

(associated with flexion of lumbar spine in the experiments quoted above) produces a similar increase in tension which largely affects the roots on the side of the flexed limb, but perhaps also those on the opposite side. Relaxation of the increased tension produced by this position is obtained at once by flexion of the knee of the limb which is being tested. The variations in the state of tension induced by these movements occur in both intradural and extradural roots. It is believed from observations made during the experiment that they are more marked in the extradural than in the intradural nerves.

To sum up these anatomical observations, it may, therefore, be said that the extradural intraspinal nerve-roots in the lumbar region are placed in the extreme anterolateral portion of the spinal canal and that they resist forces which tend to displace them from this position. This resistance is due to the normal state of tension existing in the nerves. The tension is due partly to the structure of the extradural nerve and partly to the proximity of its upper and lower attachments —both of which are relatively fixed. The degree of this tension is not constant, but varies with varying postures of the head, trunk, and limbs.

Clinical Considerations.—The observations made during operations for the removal of protruded intervertebral discs will now be considered.

In the first place it must be noted that the disc protrusion may be placed so far laterally (near the intervertebral foramen) that it may be difficult to display it at operation. Usually the displaced disc tissue is more medially placed and has a spinal nerve with its dural sheath crossing it, often on the medial side of its summit (*Fig.* 351). At other times the protrusion is still more medially placed and the nerve and its dural sheath will be found to cross its lateral portion in a trough between its summit and the lateral wall of the spinal canal. As will be mentioned later, it has seemed that this varying relationship of nerve to protrusion may account for variations in the clinical picture.

Secondly, in the majority of cases the extradural nerve is tightly stretched over or around the disc protrusion. It may require considerable force to displace the nerve medially off the protrusion. It has often appeared that this stretching of the extradural nerve could be the one factor responsible for symptoms, since the root had not been sufficiently displaced to come into contact with vertebral lamina or pedicle or the ligamentum flavum. Indeed, the lumbar spinal canal is capacious, and were it not that the extradural nerve is too fixed, it would doubtless be displaced by a disc protrusion without symptoms arising. However, it must be admitted that at times the extradural nerve may be squeezed between the protrusion and some part of the wall of the spinal canal. Even then, however, it is the fixity of the nerve which prevents its escape from compression and thus tension is probably an important factor even in such a case.

Thirdly, the possibility that adhesion between an extradural nerve and an intervertebral disc protrusion may be the cause of symptoms must be considered. Often there is no evidence of such adhesion. Indeed, at operation it frequently appears that the glistening dome of the protruded disc would facilitate movement of the extradural nerve over it—the two being separated by a little loose areolar tissue which may well have qualities

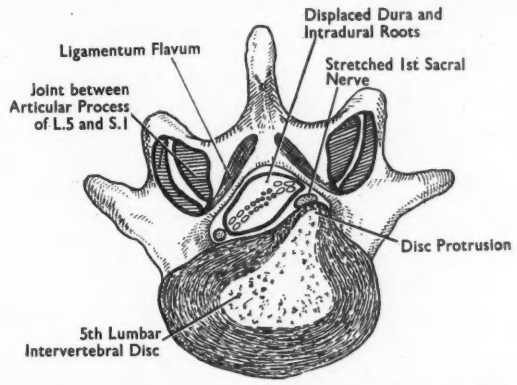
Displaced Dura and Intradural Roots
Ligamentum Flavum
Stretched 1st Sacral Nerve
Joint between Articular Process of L.5 and S.1
Disc Protrusion
5th Lumbar Intervertebral Disc

FIG. 351.—A diagrammatic drawing of a section made through a fifth lumbar intervertebral disc in which protrusion has occurred on the right. The anterior position of the first sacral nerve on the unaffected side is indicated. The fifth lumbar nerve which would curve laterally around the vertebral pedicle and above the plane of the section has not been represented.

similar to bursal tissue. In one patient in the series it was seen that a small piece of disc tissue had penetrated the posterior longitudinal ligament and pierced some of the coverings of the extradural nerve. Until these had been cut the nerve could not be displaced off the disc protrusion—which was a very large one. In several other patients in the series there has been similar difficulty in displacing the root off the protrusion because of the presence of definite adhesions between the two. Some of these protrusions were small, irregular, and hard, and had been present for a considerable time. It is difficult to account with certainty for the presence of these adhesions. Perhaps the appearances represent a late stage of the penetration of the coverings of the nerve by disc tissue as described above. Perhaps the tissue which lies between nerve and protrusion and which has been compared to bursal tissue had become scarred as the result of prolonged friction.

Fourthly, observations have been made at operation upon the effect of jugular compression on the dural theca and extradural nerve-roots. When bilateral jugular compression was applied the lumbar theca became distended. When the pressure was released it returned to its previous state. The posterior portion of the theca was now retracted to bring the anteriorly placed extradural nerves into view. On jugular compression the upper attachment of the extradural nerve was seen to move laterally, appearing to pivot around the intervertebral foramen—its

lower fixed attachment. Thus it is obvious that jugular compression, like other activities which raise intracranial pressure, produces movement of the extradural nerves in the lumbar region. Should this movement be obstructed by a protruded intervertebral disc the tension upon the root will be raised, i.e., it will be subjected to a further stretch.

The embryological, morphological, and clinical evidence upon which is based the hypothesis that stretching of an extradural nerve is the cause of the clinical syndrome in intervertebral disc protrusions is set out above. In virtue of its anatomical situation, its structure and its attachments, an extradural nerve is early affected by lesions in its neighbourhood. The only common lesion in this situation is an intervertebral disc protrusion. It displaces the related nerve to some extent, but the displacement is strictly limited, and, consequently, as the disc protrusion enlarges, the extradural nerve is stretched over it between its relatively fixed attachments. Only one extradural intraspinal nerve will usually be related to a disc protrusion. It is believed that the characteristic clinical picture of lumbar disc protrusions is largely due to the tension in this extradural nerve produced by the protrusion and to factors which modify the degree of such tension.

DISCUSSION

It has already been suggested that several of the features of the clinical syndrome cannot readily be explained on the basis of the current belief that one or more of the roots of the cauda equina are compressed between the disc protrusion and some other structure such as the ligamentum flavum. An attempt will now be made to explain certain of these features on the tension hypothesis.

In the first place certain aspects of the history given by patients with protruded lumbar intervertebral discs may be discussed. The pain is commonly increased by coughing, straining, and other efforts which, like jugular compression, raise intracranial pressure. It has been seen that the latter procedure causes the extradural nerve to move laterally. Now, since it very frequently crosses the protrusion on the medial side of its summit such a movement of the nerve will mean an increase in tension with exacerbation of pain.

Again, it is often stated by patients that certain postures aggravate their pain while other postures relieve it. While it is difficult to account for such variations on the compression hypothesis, they are only to be expected if it be granted that the disc causes symptoms by stretching a nerve. Having observed that movements of the head and lower limbs vary the tension in the nerves of the cauda equina, it is not surprising that stooping and flexion of the neck, which increase tension in these nerves, also increase the pain of patients with sciatica. Nor is it to be wondered at that flexion of the hip and knee of the painful limb is often a position of relief, for in this posture it has been seen that the spinal roots which enter into the formation of the sciatic nerve are relaxed. Occasionally the patient will have noticed that extension of the contralateral limb at the hip and knee or raising the ipsilateral arm above his head will relieve his pain. The explanation of this is less obvious, but it is thought likely that such movements may, through the dural theca, displace the stretched extradural nerve to a position in which it will be less tense (i.e., move it on to a lower level on the slope of the disc protrusion). The aggravation of symptoms by exercise and their diminution by rest might similarly be accounted for by the increased or decreased number of stretchings of the nerve which follow activity or rest as the case may be.

Patients with tumours of the cauda equina, including some patients with protruded intervertebral discs, frequently complain that they are wakened at night by their pain and that by walking around for a while they gain relief and can sleep again. The explanation of this is by no means obvious. It is possible that such exercise and the tossing about in bed to gain a comfortable position may owe their effectiveness to their producing slight displacements of the affected nerve-root or roots, so that perhaps a different group of nerve-fibres is subjected to the greatest stretch or compression. If this is so, it calls to mind the normal involuntary movements of the body during sleep, which ensure against such injury to superficial tissues as may result from immobility in the presence of paralysis or anæsthesia.

Certain of the clinical signs of lumbar disc protrusions will now be considered in the light of the tension hypothesis. Flexion of the spine is painful because it produces an increased tension in the intraspinal nerves. This, of course, means that a further stretch is applied to the extradural root already stretched over the protruded disc, with the result that there is an increase in the severity of the patient's sciatica. The sciatic pain would indeed appear to be proportional to the tension in the extradural nerve.

It has been seen that the normal lumbar lordosis is frequently reduced or even obliterated in patients with protruded lumbar discs. If a normal individual is asked to obliterate his lumbar lordosis and the movement is carefully observed, it will be seen that what takes place is a tilting upward of the anterior portion of the bony pelvis with a depression of the sacrum, so that the upper portion of the trunk is lowered relatively to the fixed lower limbs. Such a movement would have the effect of producing relative relaxation in the roots of the sciatic nerve—the opposite effect to that which follows flexion of the hip or spine. The obliteration of the lordosis is thus a mechanism which relieves tension in the sciatic nerve-roots and thus diminishes discomfort.

Scoliosis has long been recognized as a sign frequently associated with sciatica. It is a common finding in cases of protrusion of the

lumbar intervertebral discs and is at times of extreme degree. As has already been mentioned, it frequently has its convexity in the lumbar region directed towards the painful limb; sometimes the reverse is the case, and at times the scoliosis is of alternating type. The occurrence of the deformity and its variations can be readily explained on the tension hypothesis. At times the affected root surrounded by its dural sheath is placed medial to the summit of the mass of protruded disc tissue. In such a case a tilt of the lumbar spine away from the painful side might well carry the stretched root into a position of relative relaxation on the lower slopes of the protrusion (*Fig.* 352). At other times—and less frequently—the extradural nerve lies lateral to the summit of the protrusion. Here a tilt towards the painful side will allow the nerve to slide farther laterally on to a lower part of the protrusion and thus permit of relaxation. When the scoliosis is of alternating type it is believed that the extradural nerve can be dislocated from one side of the summit of the protrusion to the other (*Fig.* 353). Maximum tension is present when the nerve lies on the summit and there is relative relaxation and comfort on either side of this point. It has on several occasions been noted that in the presence of an alternating scoliosis the patient has an exacerbation of his pain perhaps associated with paræsthesia during the moments when his lumbar spine is straight. It is believed that at this time the extradural nerve is crossing the summit of the protrusion and is subjected to the maximum stretching force. During the operation on two cases showing an alternating scoliosis it was observed that the summit of the disc protrusion was placed farther medially than usual. This is what would be expected on the basis of the above explanation.

The important straight leg raising test is readily explained on the basis of the tension hypothesis. The increase in tension which develops in the extradural roots as this movement is carried out will quickly produce an exacerbation of the patient's pain when the painful leg is tested. It is due to further stretching of an extradural root which is already stretched over the protrusion. Straight leg raising of the opposite or sound leg is permitted to a greater extent, but eventually it too will often increase the patient's sciatic pain. It has already been pointed out that when straight leg raising is carried out the extradural roots on the side tested are stretched and displaced. Further, it has been stated that there is also displacement and increase in tension of the roots of the opposite side, though it is much less in degree. Should this displacement of one of the extradural roots on the side opposite to that being tested be resisted by the position of a disc protrusion or by adhesion of the root to it, the increase in tension would give rise to an exacerbation of the pain. Indeed, without any such resistance to movement, if the tension in the affected extradural root is increased by straight leg raising on the opposite side, it would be expected that there would be an increase in the patient's pain as a result of the movement. Finally, in this connexion it is necessary to explain why flexion of both hips with the knees straight should frequently be allowed to an angle considerably greater than that which can be reached when the affected leg is tested alone. It has been seen that when the hip is flexed keeping the knee extended, the lumbar extradural nerves on this side become tense, each being stretched between two attachments. At its upper end each is held upwards by the attachment of the inelastic dura to the margins of the foramen magnum and also through the attachments of this membrane to all the spinal nerves which pierce it above the level of that which is now under consideration. At its lower end each is attached to various structures in the lower limb and elsewhere. When the straight leg raising test is carried out the lower end of an extradural nerve is drawn downwards, and, as a result, the dural theca is also drawn downwards to some extent. The degree of such downward movement of the

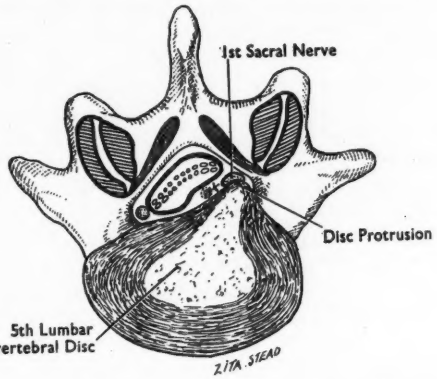

FIG. 352.—As *Fig.* 351. In addition it represents the possible medial movement of the first sacral nerve which would be produced by a tilt of the spine to the opposite side.

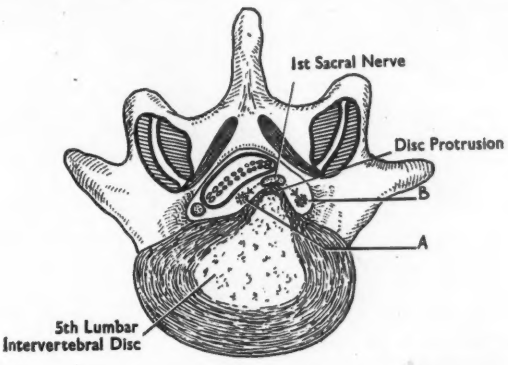

FIG. 353.—As *Fig.* 351. In addition, it represents the possible displacements (A, B) of the extradural nerve to the medial and lateral sides of the summit of the disc protrusion which it is believed occur in alternating scoliosis. They result in diminished tension in the affected nerve.

dural theca is limited, however, so that the extradural root becomes more tense as the movement progresses. It is believed that when the bilateral straight leg raising test is carried out there is a greater downward displacement of the dural theca than results from unilateral straight leg raising. This means that the tension developed in the individual extradural roots is less when both legs are raised than when one leg only is tested. On dropping the sound limb there is, therefore, an upward movement of the dural theca which causes a sudden increase in tension in the roots of the opposite side (including the root stretched over the protrusion). There immediately results an exacerbation of the sciatic pain. In addition, the displacement of dura and extradural roots towards the side tested will be prevented when the bilateral test is carried out. This would prevent the dragging of the affected extradural root on to the usually higher lateral part of the protruded disc and thus a greater degree of bilateral than of unilateral flexion can occur before pain results.

It should be noted that the straight leg raising test frequently gives rise to pain in the lower back as well as to an increase in the sciatic pain. This is doubtless the result of the spinal flexion occurring on straight leg raising. Such a movement will be painful because when a lumbar disc protrudes the intervertebral joints at its level are subjected to abnormal stresses. These joints are supplied from adjacent spinal nerves (as is the intervertebral disc itself) and the continuous strain placed on them as a result of the disc protrusion will cause low back pain. Movements which increase this strain will increase the low backache.

It might be suggested that movements of the spine would give rise to variations in the mass of the protruded disc material, and in this way be responsible for variations in the severity of the sciatica. When one considers the forces acting on the lower lumbar discs it seems unlikely that material once extruded is ever withdrawn into the intervertebral interval. Perhaps where the annulus fibrosus has not ruptured relief from pressure by recumbency might allow the disc to return to its normal situation. In the common protrusion with rupture of the annulus fibrosus it is thought most unlikely that such an occurrence could take place to a significant extent.

The explanation of the distribution of the motor, sensory, and reflex disturbances must now be considered. It has already been pointed out that these disturbances are of slight degree in the usual type of disc protrusion. Often they may be limited to the distribution of either the fifth lumbar or first sacral root. Occasionally both of these roots will show involvement, and at times the second sacral root may be affected. The dural theca and its contained roots are readily displaced to one side by disc protrusions into the lumbar canal. The usually solitary extradural intraspinal nerve (*Fig.* 351) which is related to the disc protrusion cannot be so displaced, and thus signs due to the stretching of this nerve between its fixed attachments arise. One root only is subjected to severe trauma, and for this reason signs of nervous dysfunction are often slight and the evidence of the trauma is largely subjective —i.e., sciatic pain.

As a final argument for the tension hypothesis it may be stated that it explains the benefit which may follow certain non-operative methods of treatment in these cases—a benefit not readily explained in other ways. Rest relieves pain by minimizing the number of additional stretchings of the affected extradural nerve. Sciatic nerve stretching may forcibly elongate the extradural root which crosses the protrusion so that after the elongation it is no longer subjected to stretching. Or it may act by freeing adhesions between root and protrusion so that the former can afterwards be displaced into a position in which it is less tense. Again, it is obvious that an epidural injection has the contrary effect to jugular compression—it collapses the dural theca instead of distending it. It has been seen that with jugular compression the affected root will often be carried laterally on to the higher lateral part of the protrusion; with an epidural injection the reverse movement would be expected to occur. In this way the root might be displaced off the protrusion and for as long as this displacement was maintained relief would ensue. Lastly, the spontaneous cure of sciatica which occurs after a varying period in both the initial and subsequent attacks may well be the result of elongation of the affected nerve or nerves as the result of prolonged tension. Elongation will, of course, lead to a reduction of tension and thus of pain. According to Love and Walsh (1940), some have suggested that the remissions in the sciatica result from subsidence of œdema in the protruded disc material; others that degeneration in the compressed root interrupts the pain fibres; and others that it results from return of the protruded disc tissue to the intervertebral space. It is thought that the explanation put forward in connexion with the present hypothesis may be of importance.

In this discussion it has so far been suggested that the symptoms and signs of protrusion of a lumbar intervertebral disc are largely explainable on the basis of stretching of an extradural nerve by the mass of protruded disc tissue and the variations in the degree of such stretching which occur with activity and postural alteration. Certain other points must be discussed, however. At the outset it was suggested that there were two types of clinical syndrome in lumbar disc protrusions: first, the evidence of a severe cauda equina lesion due to contusion and compression by a large protrusion; and second, the typical syndrome. It is believed that there are intermediate types of cases in which the protrusion is large, the neurological signs are more marked than usual, and the symptoms and signs result not only from the stretching of an extradural root, but also from involvement of the intradural roots related to the protrusion. Such involvement may be in

part compression, especially perhaps in the small canal at the level of the fifth lumbar disc, but is almost certainly in part due to stretching. The intradural root becomes relatively fixed at its point of attachment to the dura and displacement of either root or dura in this region will result in stretching of the intradural roots.

Another point which appears important is the site at which an extradural nerve is involved by the disc protrusion. It has been seen that the fifth lumbar and first sacral nerves are those commonly affected and that they are involved either at the point of exit of nerve from theca or slightly distal to this point by protrusions of the fourth and fifth lumbar discs. Such involvement of the fifth lumbar nerve by the fourth disc and of the first sacral nerve by the fifth disc (*see Fig.* 348) should always be demonstrable at operation. But does a protrusion ever occur far laterally in the intervertebral foramen when either the fourth or fifth lumbar nerves would be involved ? If this did occur the lesion might not be demonstrated at operation. It should be noted that the fourth and fifth lumbar nerves pass laterally around the lower margin of a vertebral pedicle and through the upper portion of an intervertebral foramen. Since the intervertebral disc forms the anterior boundary of an intervertebral foramen in its lower portion only, should it protrude in this situation the nerve might well escape involvement. Clearly a large protrusion in this situation—if it occur—might compress an extradural nerve against the margins of the foramen. There has, however, been no evidence of a protrusion in this situation in the series, nor has any reference to its occurrence been found in the literature.

It is thus believed that the hypothesis that the typical intervertebral disc protrusion produces symptoms by stretching the extradural portion of a related intraspinal nerve provides a ready explanation of the clinical features associated with this lesion. While compression may have some bearing, it is considered that the large lumbar canal can accommodate protrusions of such size as usually occur without there resulting pressure on any of its contents ; the dura and its contained roots are displaced, but the possibility of displacement of the extradural nerve is limited and it is therefore stretched when the limit of its mobility is reached. When the protruded disc is of large size and the extradural roots relatively mobile, it is obvious that one of them may be carried posteriorly by the protrusion and compressed between this and the vertebral lamina or ligamentum flavum. Adhesion between nerve and protrusion is sometimes found. When it does occur, by limiting the possibility of displacement of the nerve over the protrusion into positions of relaxation, it would be likely to contribute to the symptoms. Friction between nerve and protrusion may also aggravate symptoms. It is believed, however, that stretching of the affected nerve is the most important factor.

SUMMARY

1. The clinical syndrome of protrusion of the lumbar intervertebral discs associated with sciatica is considered.

2. A modification of the straight leg raising test which has been found of value is described.

3. When certain lesions have been excluded, the presence of this clinical syndrome allows of the diagnosis of protrusion of a lumbar disc without contrast radiography being necessary. Indeed, in many cases it can be decided on clinical grounds whether the fourth or fifth disc is involved.

4. The pathogenesis of the syndrome is considered and the hypothesis is put forward that the usual type of lumbar disc protrusion causes symptoms and signs of nervous disturbance by stretching the related intraspinal extradural nerve.

5. The evidence for this hypothesis is discussed and is based on embryological, morphological, and clinical considerations.

6. Features of the clinical picture which cannot readily be explained otherwise are considered in the light of the hypothesis.

It is a very pleasant duty to record my gratitude to the many who have assisted in this work. In the first place there is a debt to those who have referred cases of sciatica to me since 1937. These cases have come from many sources, but especially from the members of the staff of St. Bartholomew's Hospital—in particular, Mr. S. L. Higgs and Mr. Jackson Burrows. In carrying out the dissections of the cauda equina I have been helped by my late house surgeons—Mr. R. C. Connolly and Mr. J. Haile. The histological preparations I owe to the co-operation of Dr. J. M. Ross. Finally Miss Z. M. Stead has ably performed the task of illustrating my conception of the aetiology of the clinical syndrome.

REFERENCES

BRADFORD, F. K., and SPURLING, R. G., *The Intervertebral Disc*, 1941. C. C. Thomas.

BRADFORD, F. K., and SPURLING, R. G., *Jour. Amer. Med. Assoc.*, 1939, **113**, 2019.

DANDY, W. E., *Ibid.*, 1941, **117**, 821.

HAMPTON, A. O., and ROBINSON, J. M., *Amer. Jour. Roentgenol.*, 1936, **36**, 782.

LOVE, J. G., *Proc. Staff. Meet. Mayo Clinic*, 1936, **11**, 529.

LOVE, J. G., and WALSH, M. N., *Arch. of Surg.*, 1940, **40**, 454.

MCKENZIE, K. G., and BOTTERELL, E. H., *Canad. Med. Assoc. Jour.*, 1942, **46**, 425.

MIXTER, W. J., and BARR, J. S., *New Eng. Jour. Med.*, 1934, **211**, 210.

MIXTER, W. J., and AYER, J. B., *Ibid.*, 1935, **213**, 385.

NAFFZIGER, H. C., INMAN, V., and SAUNDERS, J. B. de C. M., *Surg., Gynecol. and Obst.*, 1938, **66**, 288.

PENNYBACKER, J., *Lancet*, 1940, **238**, 771.

REICHERT, F. E., *Jour. Amer. Med. Assoc.*, 1937, **109**, 1270.

SCOTT, M., and YOUNG, B. R., *Arch. of Neurol. and Psychiat.*, 1937, **38**, 1126.

SEMMES, R. E., *Yale Jour. Biol. and Med.*, 1939, **11**, 433.

THE USE OF IRRIGATION ENVELOPES IN THE TREATMENT OF LACERATED WOUNDS AND COMPOUND FRACTURES

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It is usually taught that the healing of a wound requires rest, that the prevention of infection is facilitated by rest, yet the restoration of function requires active movements. It must be the endeavour of modern methods to reconcile these two apparently opposing principles. If infection can be adequately controlled and yet movements allowed from the start, then we have achieved a definite advance in the treatment of compound injuries of the limbs, and particularly so in the structures where movement is highly specialized and immobilization, therefore, most detrimental, e.g., in the hands and fingers. The use of an occlusive envelope, as introduced by Bunyan and developed by Stannard, controls infection even when active movements are allowed from the start. It brings an ideal within the bounds of practical possibility and introduces a simple and effective method of dealing with severe injuries. Further, the wound is always ready for inspection without disturbing the dressings, as the silk envelopes are semi-transparent.

The constantly repeated irrigation of wounds as a method of treatment has appealed to many workers and became established to some extent during the last war, when it was known as the Carrel-Dakin method. The technique demanded frequent attention and the solution employed was often irritating. However, the theory that the wound acted as a culture medium and that repeated irrigation would prevent this, was probably a sound one. Carrel and Dehelly[1] showed that the destruction by antiseptics of micro-organisms infecting a wound was possible, and gave an excellent account, based on bacteriological evidence, of the topography of wound infection, which may be summarized as follows: "In fresh wounds under 6 hours which are not bleeding, rods and cocci are sometimes found, but these are localized in the regions close to foreign bodies; frequently no microbes are visible. At the end of 12 hours, examination of sinuses revealed microbes more constantly and in greater abundance, and after 24 hours they were over almost the whole extent of the wound."

Even with the most careful excision it is impossible to avoid leaving some micro-organisms behind, which in 12 to 24 hours multiply into vast numbers in any blood-clot which may form, so that suppuration is liable to follow. The Bunyan-Stannard[2] method has introduced a simple, efficient, and non-irritating method of providing frequent irrigations without disturbing the dressings. A careful wound cleansing with excision of devitalized tissue must first be undertaken, followed by irrigations three times per day, starting within 12 hours of the initial cleansing. This appears to disturb the incubation of the micro-organisms in the wound and prevents suppuration so effectively that active movements can be instituted from the first without fear of spreading the infection. In the treatment of injuries to the limbs this preservation of movement from the start is of fundamental importance.

OUTLINE OF THE METHOD

A series of 32 cases is tabulated below, and although space will not allow for the details of all the cases to be given, some are selected because they either illustrate the principles employed or are of particular interest. But in the first place, in order to avoid repetition, an outline of the general procedure adopted will be given.

The wound is cleansed under a jet of a 1–5 dilution of 1 per cent electrolytic sodium hypochlorite (E.S.H.), which is directed on to the wound and its surroundings from a douche can or by means of a Higginson syringe. This jet is usually controlled by an assistant while a thorough toilet of the wound in carried out. *Great care is taken to remove all grossly contaminated devitalized tissue and foreign bodies (if readily accessible).* There is no doubt that patience and care at this stage affect the success of later results. Again, in the words of Carrel and Dehelly, "Gauze compresses, blood-clots, and dead tissue have a particularly harmful effect because they protect the bacteria from the attacks of the antiseptic". The skin edges, unless devitalized or irregular and ragged, are not excised, the removal of viable skin by excision being illogical and found to be unnecessary. The removal of devitalized or grossly contaminated muscle or areolar tissue is very important and should be thorough. If the cleansing is meticulously performed and the wound recent (under 8 hours), it is often safe to employ deep sutures in important structures, nerves, tendons, etc., and also to suture the skin (*Cases* 13 and 26). The greatest care must be taken to preserve the main nerves intact. This may seem obvious, but the exact anatomy is occasionally forgotten and injury occurs during débridement. If the initial clinical examination shows that the nerve conduction is interfered with, then an Esmarch's bandage and pneumatic tourniquet are usually advisable.

After the toilet of the wound is completed an occlusive envelope is applied and a further irrigation with 1–5 E.S.H. solution is carried out

at once to sterilize the interior of the envelope. Subsequently the wound is irrigated three times per day with a 1–20 E.S.H. solution. The irrigation fluid should always be at a temperature of 100° F., and its cleansing effect is increased by the lowering of surface tension if a solution of sodium or ammonium lauryl* sulphate is added, a strength of one drachm to one pint of hypochlorite having been used in this series of cases. It is only advisable to use this detergent solution for the initial cleansing of the wound and perhaps occasionally afterwards if the bag becomes difficult to clean, because the repeated and prolonged use of lauryl sulphate has been found to lead to some irritation of the superficial layers of the wound and skin.

After each irrigation the envelope must be thoroughly drained; it must not be used as a wound bath, and should be dried on each occasion by a current of warm filtered air and the openings sealed. Excessive inflation must be avoided in view of its likely damage to the envelope and

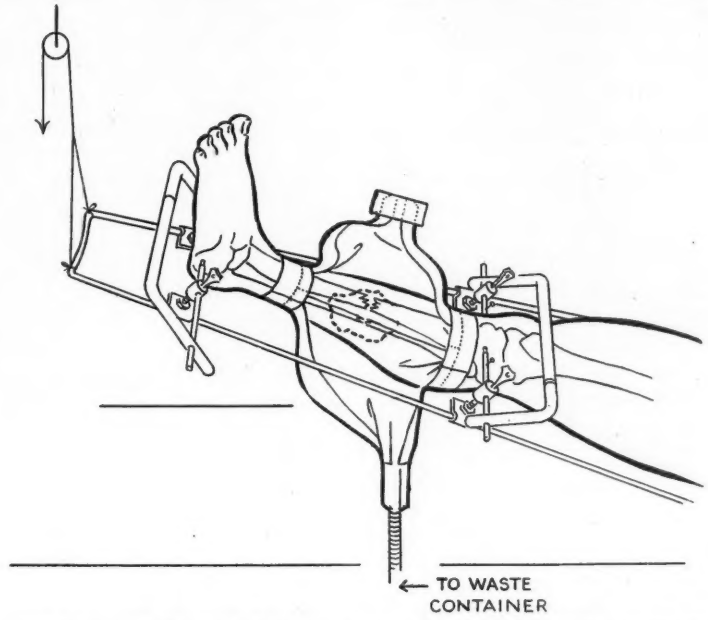

FIG. 354.—Compound fracture of tibia and fibula showing occlusive envelope applied to the wound and fixation of the fracture by Steinmann's pins, clamps, and a Thomas splint.

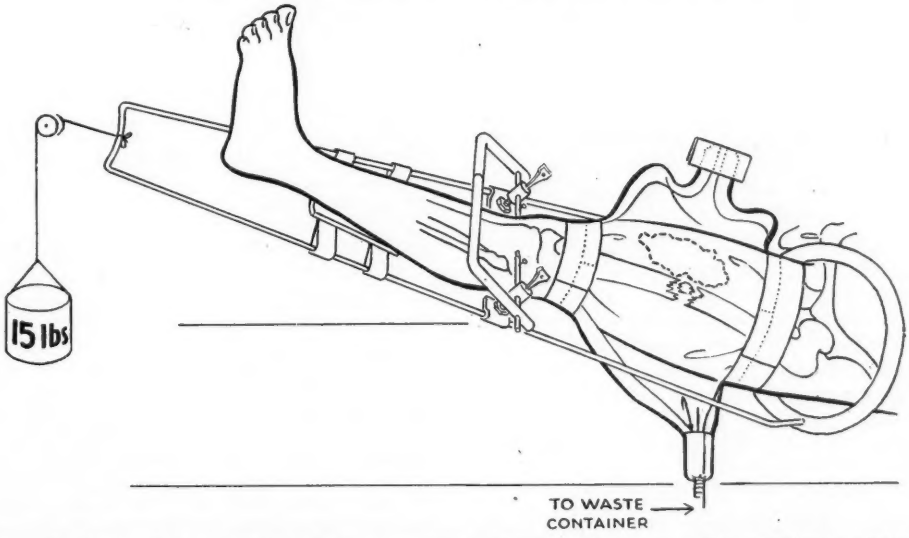

FIG. 355.—Showing method of applying bag to a compound fracture of the femur. The extension is obtained first of all by the pressure of the ring of the Thomas splint against the tuber ischii, and then on return of the patient to the ward a 15–25-lb. weight is attached, so as to reduce the pressure on the skin covering the tuber ischii. Counter-weight is obtained by tilting the bed.

* A detergent derived from coconut oil.

production of leakage. If it is necessary to control hæmorrhage by pressure, then this should be applied outside the envelope, there being no need, of course, for dressings to be sterile for this purpose.

If a fracture is present as well as other injuries, it can be controlled by mechanical means, e.g., Steinmann's pins clamped to the side bars of a Thomas splint in the case of the femur or tibia and fibula (*Figs.* 354–356). Later, even in compound fractures, plating may be employed with a non-toxic steel or vitallium (*Cases* 29–32). The description of the cases is given in some detail so that the extent of the injury can be appreciated fairly accurately. The term 'absence of general reaction' used in the case reports means no rise of temperature or pulse frequency, while 'absence of local reaction' means no redness of the skin, no tenseness, no spreading œdema, and no severe pain or throbbing.

FIG. 356.—This illustrates the method used for a fracture of the femur and of the tibia and fibula, and is a combination of *Fig.* 354 and *Fig.* 355. It can be appreciated that the tibial fracture is fixed in the apparatus and then the control of the femoral fracture is readily obtained.

The main object of this paper is to show the use of the occlusive envelope as an initial method of treatment for severe injuries, a point of particular interest at the present time in view of the large number of such cases and their complex features likely to be met with under war conditions.

CASE REPORTS

Group A: Lacerations (13 Cases).—All except 3 of these cases were severe injuries. The wounds healed well and only in one case was there any gross sepsis. Reaction both local and general was absent or mild in all the others in spite of active movements from the start.

In this group details of *Cases* 2, 3, 4, and 5 are omitted as they are similar to *Case* 1, but illustrative cases of this group include the following:—

Case 1.—J. S., aged 65, a leather worker, sustained a crush injury to his right hand and forearm in a leather press. The little finger, palm, dorsum, and lower third of the forearm were degloved of skin, the bulk of the flap so produced was 6 in. long and remained attached proximally by a fairly wide pedicle. The muscles and tendons of the wrist and forearm were lacerated, the tendons being torn but none of them actually severed.

All dead material was removed within 6 hours of the accident. This involved the sacrifice of a little devitalized skin, areolar tissue, and muscles under a jet of E.S.H. (1–5), and then after the whole area and all the pockets had been thoroughly cleaned, the skin-flap was loosely sutured back into position and a Bunyan bag applied.

The usual routine of irrigation with the 1–5 solution immediately after the envelope was in position and three times a day after that with 1–20 E.S.H. was carried out.

Active movements were commenced the next day, the absence of pain being remarkable, and there was no rise of temperature for 5 days, when an evening temperature of 99° F. was recorded and the irrigations became somewhat painful. A weaker solution (1 per cent) was used because of this pain, which in three days disappeared and the temperature returned to normal. The bag was changed in three weeks, some small superficial sloughs over the raw areas were removed, and another envelope applied.

After 5 weeks the condition was as follows: The wound was healed except for a healthy granulating area extending along the front of the wrist, the ulnar border of the palm, and the whole of the 5th finger. Movements of the thumb, index, and ring fingers showed slight limitation of flexion of the interphalangeal joints and the metacarpo-phalangeal joints. The middle finger had been previously amputated, the 5th finger had movement at the metacarpo-phalangeal joint only.

At this stage the bag was removed and the 5th finger amputated, a Thiersch graft being applied to the granulating area. The graft was over a 90 per cent take, and the wound was dry and healed in another 2 weeks, i.e., 7 weeks from the time of the injury. There was almost complete return of movements in the index and ring fingers. Wrist and thumb

movements were full and the patient able to manage light work.

Comments.—This case illustrates maintenance of function of the wrist and fingers and the preservation of partially separated but not devitalized skin in a severe laceration of the hand. Healing was rapid, sepsis as shown by local and general reaction was negligible (the temperature never rose above 99°) in spite of active movements from the start.

Case 6.—C. B., a man aged 33, sustained from a broken glass in an air raid a cut on the flexor aspect of the 2nd and 3rd fingers of the left hand which severed the sublimis and profundus tendons of both fingers. The wounds were irrigated thoroughly, the skin sutured, and a Bunyan bag applied. No attempt was made to suture the tendons. There was no local or general reaction.

Passive movements of the interphalangeal joints were instituted from the start and active movements of the metacarpo-phalangeal joints were encouraged, flexion being possible by the action of the intrinsics, which were intact. These movements were readily obtained in the envelope, and in 14 days, when the wounds were healed, the bag was removed and full, free, passive movements of the interphalangeal joints were present. This is an important attainment, as if full, free, passive movements can be obtained then a palmaris longus tendon transplant later has a good chance of success, and as the lesion involved the index and middle fingers of the hand the reconstruction and recovery of active flexion was very desirable.

This patient unfortunately possessed only a rudimentary palmaris longus tendon on each side and a full transplant of the proximal portions of the severed sublimis tendons on the distal ends of the severed profundus tendons was used. Suture and reconstruction was carried out on the lines developed by Bunnell, 8 weeks after the primary injury; stainless steel wire was used for suture material, and three weeks after operation there were full passive movements of all the joints and also a small range of active movements in the metacarpo-phalangeal joints.

Eight weeks after the tendon reconstruction operation there was a full range of active movements in the metacarpo-phalangeal joints, 20° of active movement in the proximal interphalangeal joint, and 10° of active movement in the distal interphalangeal joint, full passive movements at all joints still being present. In short, a very useful range of active movement was present at this stage.

Case 7.—Sgt. D., an R.A.F. observer, sustained an injury to the right elbow from a propeller, the blade slicing off a thin flake of the olecranon and the whole of the attachment of the triceps muscle. The ulnar nerve was exposed and bruised, but intact. The elbow-joint was completely opened posteriorly. Within three hours of the injury the wound and joint were thoroughly irrigated, a few loose threads of tendon and bits of bone were removed, but excision of skin was not required. The muscle was sutured to the tissues around the olecranon with thread and then the skin was closed as in a clean operation.

There was no general or local reaction at all and 45° of active movements (180°–145°) was present on the third day. On the sixth day he was, however, transferred to another hospital, where a posterior plaster slab was applied for two weeks, with a result that progress was retarded and movements became reduced to less than 20°.

It took another three weeks of active movements to regain the function which he had had on the third day. Fortunately, in spite of the delay due to this period of splinting, function gradually returned with active movements and 180°–90° with full pronation and supination was present in 8 weeks' time, the wound being soundly healed by first intention. In another three weeks movements were 180°–60° and power was returning rapidly. He was returned to his job as an observer about three months after the accident.

Comment.—This case illustrates the striking advantage that the envelope method has in maintaining function. The treatment was interrupted on the sixth day and a splint applied, with the consequent loss of the range of movement already regained. As a result of two weeks' splinting it took three weeks to obtain the movements which had been present on the third day.

Group B: Bullet Wounds (7 Cases).—One case died of gas gangrene, but this was complicated by an abdominal wound. There was no reaction in the others, and full and rapid recovery was obtained in two cases.

Case 20.—M. M., a sergeant in the R.A.F., sustained a severe injury to the left forearm as a result of a shrapnel wound, multiple pieces of metal entering on the flexor aspect and bruising the median nerve, lacerating the flexor tendons, shattering the ulna into multiple splinters, severing the ulnar nerve, and emerging through several exit wounds along the ulnar border and partially amputating the 4th and 5th digits.

The through-and-through wounds were completely cleansed by irrigation and as these wounds could not be completely excised this method was particularly useful, as metallic foreign bodies, loose pieces of bone, and pieces of clothing were washed out. The amputation of the 4th and 5th fingers, including their metacarpals, was completed so as to leave a flap of skin which could be sutured into position and the envelope applied.

Local reaction was absent and pain slight. No immediate splinting was employed as the radius was intact. There was some general reaction and the temperature rose to 101° but soon subsided, and ten days later the bag was removed, the stitches were taken out, tulle gras was applied, and a plaster cast, leaving the thumb and remaining 2nd and 3rd fingers free, was put on. At this stage the patient was transferred to another hospital.

Group C: Compound Fractures of the Long Bones of the Limbs (12 Cases).—The progress of the wounds in all these compound fractures was very satisfactory. Four of the cases were plated, two of them successfully, one other is satisfactory, but was very severe and is not yet finished, while in the fourth, also a very severe injury, the plate was not firm and a closed plaster was employed as well.

The use of the envelope does not combine well with plaster immobilization, but the employment of Steinmann's pins, special clamps,[3] and a Thomas splint for fractures of the femur and tibia and fibula for the first week or so has been most satisfactory and is a suitable fixation while the wound is treated by the Bunyan bag. Further

details are given in the actual cases and some other points discussed later. In one case amputation was performed after transfer to another hospital.

Illustrative cases of this group are described :—

Case 21.—T. H., a male boot operative aged 56, sustained a compound comminuted fracture of the left femur and a simple fracture of the left radius and ulna as a result of falling debris in an air raid.

The wound was 4 in. long on the left thigh and into it cement, dirt, and plaster had been blown. A considerable degree of shock was present and this received first consideration, a simple gauze and sulphanilamide powder dressing being applied to the wound.

Some 12 hours after the infliction of the wound the cleansing operation and the application of the envelope were carried out. A Steinmann pin was inserted into the tubercle of the tibia and the whole patient placed as in *Fig.* 355. (A closed plaster was also applied to the radius and ulna after reduction.)

In 8 hours the usual irrigations were started. There was no post-operative rise of temperature or pulse and the wound showed no local reaction and rapidly became a clean granulating wound. After 10 days the case had to be transferred to another hospital with a change of staff. Two large openings were cut in the envelope apparently to make the irrigation easier. The wounds remained clean, however, and when seen some 6 weeks later the envelope had been removed and there was a clean granulating surface. The fracture was supported in the same Thomas splint, but had been allowed to angulate backward, and so arrangements had been made for the case to be transferred to yet another hospital.

Case 23.—F. C., a male aged 49, sustained a compound fracture of the tibia and fibula inflicted by falling debris during an air raid. The laceration of the soft tissues was extreme, and powdered cement, plaster, and dirt were deeply inground into the wound, the bone was comminuted, and splinters of bone could be seen lying in the wound. Within 8 hours of the raid the wound was thoroughly irrigated with 20 per cent E.S.H. and then Steinmann's pins placed through the tubercle of the tibia and the os calcis and an occlusive envelope applied as in *Fig.* 354.

The post-operative period was remarkable for the absence of reaction either general or local. The wound was irrigated with 5 per cent E.S.H. three times daily in the usual manner. Later the case was transferred to another hospital.

The case was followed up and the progress of the wound and the general condition of the patient were good. The final result of the case is, however, not known.

Table I.—TABULATION OF CASES
(For further details see Case Reports)

No.	Type	Severity	Temperature Reaction in 1st Week	Result
GROUP A: Lacerations and Crush Injuries (13 Cases).—				
1	Crushed and lacerated hand	Severe	Normal until 5th day, then 99° F. for 3 days	Excellent and rapid recovery
2	Crushed and lacerated hand	Severe	100° F. on 3rd day, normal after	Good and still improving
3	Crushed and lacerated hand	Severe	99·8° F. on 2nd day, normal after	Very good
4	Crushed and lacerated fingers	Moderate	99° F. on 3rd day, normal after	Very good and rapid
5	Crushed and lacerated foot	Severe	99·8° F. 1st and 2nd days, normal after	Good
6	Cut flexor tendons	Minor	No reaction	Good healing. Tendon transplan later
7	Lacerated elbow-joint	Moderate	No reaction	Excellent, full recovery
8	Lacerated leg	Moderate	No reaction	Full recovery
9	Lacerated hand	Severe	No reaction	Good recovery
10	Compound dislocation—fingers	Minor	No reaction	Full recovery
11	Compound fractures—fingers	Severe	No reaction	Good recovery
12	Crushed right hand	Severe	101° F. 1st day, thereafter never above 99° F.	One finger amputated—wound healed well
13	Crushed left foot	Severe	101° F. next day, settled in 7 days	Foot saved—will require skin-graft
GROUP B: Bullet Wounds (7 Cases).—				
14	Hand	Minor	No reaction	Full recovery in 17 days
15	Leg	Moderate	100° F. 1st day, then normal	Full recovery
16	Hand	Moderate	99° F. 1st day, then normal	No sepsis, recovery slow
17	Left arm	Moderate	99·6° F. 1st day, then normal	No sepsis, nerve lesion present
18	Multiple, chest and ankle	Moderate	No reaction	Wound healing well and ankle movements good
19	Multiple, abdomen and legs	Severe	101° F. next day and rising pulse	Died of gas-gangrene
20	Shrapnel wound, forearm and hand	Severe	99° F. occasionally in 1st 7 days	Rapid healing of wounds
GROUP C: Compound Fractures (12 Cases).—				
21	Femur, comminuted	Severe	No reaction	Healing of wound excellent
22	Tibia and fibula, comminuted	Severe	Mild reaction in initial stages	Transferred and amputated
23	Tibia and fibula, comminuted	Severe	No reaction	Later transferred, wound healing
24	Tibia and fibula, comminuted	Severe	No reaction	Later transferred, wound healing
25	Femur, comminuted	Severe	100·4° F. 1st day, rapidly settled	Transferred, wound healing well
26	Tibia and fibula, comminuted	Severe	103° F. 3rd day	Wound healed well
27	Radius, comminuted	Moderate	No reaction after envelope applied	Excellent healing and return of function
28	Femur, comminuted	Severe	101° F. 3rd day, then subsided	Wound healing well, transferred
29	Tibia, comminuted, and femur	Very severe	No reaction	Excellent healing
30	Radius and ulna, comminuted	Very severe	102° F. 2nd day	Wound soon ready for skin-grafting
31	Tibia and fibula, comminuted	Very severe	99·8° F., later 101° F.	Wound soon ready for skin-grafting
32	Tibia and fibula, comminuted	Severe	99° F. 1st day, then subsided	Wound soon ready for skin-grafting

Case 29.—Sgt. K., an army despatch rider aged 21, sustained a compound comminuted fracture of the upper third of the tibia and a simple oblique fracture of the femur as a result of a head-on crash at 40 m.p.h. with a lorry. There was considerable displacement of the fragments.

After the usual cleaning of the wound a Steinmann pin was inserted through the tubercle of the tibia and the os calcis and a Thomas splint applied, the fracture of the tibia and fibula being controlled by clamping the Steinmann pins to the side bars of the splint and the fracture of the femur by making the ring of the splint a snug fit against the skin, conserving this process by applying weight extension to the end of the Thomas splint (*Fig.* 356). In this way a satisfactory control of both fractures was obtained. There was no reaction either general or local.

Three weeks later the wound over the tibia was dry and covered with a scab, the bag was removed and a piece of sterile stockinette was stuck on to the skin of the leg with mastisol. Then through this stockinette and through a separate incision the tibia was plated. Two stainless steel plates were used, one on the antero-medial surface and one on the lateral surface of the bone. The femoral fracture was plated at the same time, also using two plates of the same material, one on the anterior and one on the lateral aspects of the bone. All the wounds healed soundly without any evidence of sepsis. No external splints or plaster of any sort were used and active movements were started three days after operation. Within 14 days the patient could lift the whole leg without assistance and knee movements were returning. A few days later he was transferred owing to the pressure of air-raid casualties.

He was seen a few weeks after transfer; the wounds were dry and practically completely healed. There was no fixation of the fractures except the internal plates, and active movements were steadily increasing.

Some 14 weeks after the operation the wounds were soundly healed. Knee movements were 180°–45° and both bones were firmly united.

Comment.—This case illustrates the excellent recovery which can be obtained in a double fracture of the leg, one of which was compound, by plating. It is desirable to apply the plate through a completely clean and separate incision after the wound is practically dry or has been skin-grafted.

Table II.—Severity of the Lesions

	Cases
Very severe	4
Severe	17
Moderate	8
Minor	3
Total	32

Table III.—Results of Wound Healing

	Cases
Excellent	7
Good	22
Slow	2
Died	1
Total	32

Table IV.—Nature of Accidents

	Cases
Air raids	8
Industrial accidents	7
Road accidents	5
Flying accidents	4
Army manœuvres	5
Sports	3
Total	32

DISCUSSION

These cases illustrate the many advantages of this method and the results are similar to those obtained in the last war by Carrel. It is necessary, however, in the present instance, to observe the exact technique in full detail, just as it was necessary to follow the Carrel technique in his former method, for as Carrel remarks, "The substitution of saline for hypochlorite is to be deplored". In fact, the words of Carrel in his book, *The Treatment of Infected Wounds*, may well be quoted here: "The deplorable results obtained in several hospitals by surgeons who believed they were using our methods, but who in reality were altering them according to their fancy, make clear the necessity for observing exactly the directions . . ."

This envelope method is simpler than Carrel's method and has three added advantages in that it protects the wounds from further outside infection, permits free movement and locomotion, and also allows immediate inspection and palpation of the wounded area. It may be stated that in the present series great care has been taken to adhere scrupulously to the published technique of the method.

1. Injuries of the Hand and Fingers.—Next to the brain, the hands are more highly developed in man than in any other living creature, and such is the intricacy of their mechanism that repair has often to be given up. The treatment of finger injuries is one of the most important and yet one of the most deplorable aspects of surgery. If vigorous active movements can be instituted early, then an advance has been made because function can be maintained and amputation avoided. The other possibility of a reconstruction by operation and later restoration of function is too slow and uncertain, except under special circumstances.

There are difficulties with the envelope method, of which the most important is dealing with the fixation of a fracture combined with the wound. Sometimes the fracture can be disregarded, but more often than not some form of splinting is required. The usual practice is to use a wire splint, padded and fixed on the flexor aspect of the finger and held in place by a plaster on the forearm, but irrigation under these conditions is made more difficult and in some of these cases internal fixation may be the answer. This is dealt with separately and in more detail in the next paragraph. In any case there is one essential point: if the metacarpo-phalangeal joints must be fixed then they must be flexed. The use of transfixion pins and excessive extension of the fingers should be avoided, as, unless the greatest care is exercised, they are a potent source of gangrene.

2. Fractures.—The use of an occlusive envelope in the case of compound fractures is very satisfactory, provided that the reduction and fixation of the fracture can be carried out. In the case of the common compound fractures of the leg, namely, those of the tibia and fibula and of the femur, the initial control of the fractures can be obtained simply and effectively by the use of Steinmann's pins, a Thomas splint, and the special clamp[3] as shown in the illustrations (*Figs.* 354–356).

The wound is thoroughly cleansed; the pins are then placed, the upper one in the tibia at the level of the tubercle and the lower one in the os calcis, and a special envelope (called an open type for Hodgen splint) applied. If this special envelope is not available a knee or elbow variety can be threaded over the foot and put in place after the wound has been cleansed, but before the Steinmann pins are inserted.

The use of the os calcis for the lower pin does not give rise to any trouble provided that careful asepsis is observed during its introduction and that it is removed as early as possible. This is within 14 days of the accident, by which time plaster or plating has been applied as a means of fixation.

Other fractures are more difficult to control, as the envelope does not combine well with the use of plaster-of-Paris as a means of fixation in the early stages.

Compound fractures of both bones of the forearm are particularly difficult to deal with, and in *Case* 30 internal fixation by vitallium plates was used as soon as the danger of infection was over. A pedicle skin-graft was also required in this case and the progress of the case was most gratifying, there being no gross sepsis at any stage.

Wounds can be rendered so clean and free from reaction that the plating of compound fractures can be carried out. A word of warning is, however, desirable here in that this type of work should be carried out only by those experienced in bone surgery, as scrupulous asepsis is required, coupled with a thorough understanding of the mechanics involved. The plating of compound fractures may be carried out either immediately through the original wound or some days later through a separate clean incision.

In the case of fractures of the leg where adequate temporary fixation can be provided, then operation at a later stage is to be preferred. In the case of fractures of the humerus and the radius and ulna, however, where temporary fixation is difficult, and where the stresses and strains imposed on the fracture site by the weight and leverage of the limb are not so great, then immediate fixation of the fracture by vitallium plates and screws may be used. These may be inserted through the original wound, enlarged if necessary, and if used in suitable cases lead to a far better and speedier functional recovery than can be obtained by other methods.

Vitallium is to be preferred to stainless steel as there is less reaction with the electrolytic sodium hypochlorite.

Plating of compound fractures should, however, not be carried out unless the right facilities are available. The application of an unpadded plaster cast when the wound has healed is a much safer procedure for general use in the lower limbs.

3. Speed.—Deplorable as the main aim in most peace-time surgical procedures, speed becomes important under certain war conditions. A thorough toilet is desirable, as it leads to rapid healing and sometimes allows of primary suture, yet where the general condition of the patient is poor or where a large number of casualties are waiting to be dealt with then rapid work is necessary.

Under these conditions, an irrigation only of the wound is justifiable, as it is much more rapid and much less shocking than excision. Dirt may need to be scrubbed out with a brush, the wound thoroughly irrigated and left widely open. A bag is applied in the usual manner and the devitalized tissue removed at a later date (in a week or so) when it becomes apparent as sloughs. Healing under these conditions is not so rapid, but in no case was there any spreading sepsis seen, and it appears that devitalized tissue can be left behind (when speed is required) with impunity as long as free access for irrigation and drainage is present. The dangerous wound is the deep penetrating wound which is grossly contaminated, and this type is best opened widely, washed out, and left open.

4. The Co-operation of the Patient.—The confidence and active co-operation of the patient is readily obtained by encouraging active movements from the start, and this is an important factor if rapid return of function is desired. The only case where this failed was *Case* 16, and there was good reason to believe that this was a self-inflicted wound—in other words, an unwilling soldier, and as such an undesirable patient from a surgeon's point of view.

5. The Relief of Pain.—This was a most impressive feature of the treatment. Pain is difficult to assess accurately, but in this series of patients severe pain was noticeable only by its absence.

6. Transference of Patients.—Owing to the pressure of air-raid casualties, continuity of treatment and follow-up have been interrupted at times. As an emergency measure some of the cases had to be transferred to centres 50 to 100 miles away. Although the cases were cared for by competent surgeons, there is no doubt that such a change was detrimental to recovery, as not only did it interrupt continuity of treatment under the initial accident service, but may have jeopardized the life and limb of the patient.

7. Reaction to Injury.—These case notes show that if there is more than a mild reaction (i.e., if the temperature rises higher than 100° F.

in an adult during the first few days), drainage of the wound is inadequate and probably due to a faulty initial operation, the wound being inadequately cleansed or an unsuitable wound sutured. Such a reaction must not be allowed to continue with the hope that it will subside, but is a definite signal that active steps must be taken immediately to obtain better drainage and free irrigation of the wound.

Other Uses.—The envelope method has been used for many other conditions; the treatment of burns has been dealt with by other workers,[2,4,5]; as a first-aid method it is, in my opinion, excellent, being small in bulk, simple in application, and efficient in action, and should be valuable in the Services. As a method of cleaning up granulating areas with sloughs prior to skin-grafting it is also very useful, and for dealing with infections of the hand it is ideal. It has been employed in some cases of acute osteomyelitis after drainage of the abscess and was satisfactory, but the closed plaster technique has a big advantage in these cases, especially in children, since dressings are completely eliminated.

CONCLUSIONS

Primary union by suturing after meticulously careful excision is ideal, and after this an occlusive envelope makes an excellent form of dressing as it allows inspection and active movements without risk of introducing infection. Sometimes, however, it is impossible or unwise to close the wound and then the real use of the bag is appreciated, and its use for 4 or 5 days as a preliminary to skin-grafting is excellent.

The occlusive envelope method of treating wounds, being a complete reversal of the closed plaster technique (previously employed), was started with some misgiving, but the results of the first few cases showed that it was sound and its selection as the method of choice was soon to follow. However, the details of the method must be appreciated and carefully carried out if success is to be obtained. The processes of recovery seem to be accelerated by this envelope method, but in order to obtain excellent results daily care and untiring drilling of the patient to persist with active movements are required.

The treatment described is, in fact, simply a new method of carrying out old principles, and some may say that it is a swing back to the days of Lister, but it promises to be a most effective way of controlling infection of the wound and especially of preventing that spread of sepsis which frequently occurs after 24 hours. The control is sufficient to allow much earlier active movement, so that function can be maintained rather than restored afterwards, a big advance in the treatment of injuries of the locomotor system.

Active movements from the start must be the aim; active movements mean the patient's co-operation. If co-operation (and not opposition as is so often the case) can be obtained, then rehabilitation is shortened. This ideal is easy if active movements are practised from the beginning, but becomes increasingly slow, painful, and difficult both for the surgeon and the patient the longer the lapse of time between injury and the beginning of these exercises.

SUMMARY

The use of the occlusive envelope and frequent irrigations in the treatment of lacerations, bullet wounds, and compound fractures is described and a report on 32 cases given.

The main conclusions resulting from the trial of this method are :—

1. It is a simple method of dealing with wounds. The cleansing of dirty wounds is very effective, so that healing or preparation for skin-grafting is rapid.

2. Sepsis can be controlled so that active movements can be instituted immediately.

3. It is an excellent method for dealing with compound fractures, provided that a suitable method of dealing with the fracture can be employed. The plaster-of-Paris technique is not suitable, and open plating may be difficult because of the electrochemical reaction around the plate as a result of the use of an electrolyte solution. The use of Steinmann's pins, transfixing the fragments and then clamping the pins to the side bars of a Thomas splint, has been found to be very suitable for fractures of the tibia and fibula and for those of the femur.

Most of the cases were very severe injuries, one case of multiple bullet wounds dying of gas gangrene, but apart from this the cases were on the whole remarkable for freedom from pain and absence of reaction, both general and local.

REFERENCES

[1] CARREL, A., and DEHELLY, G., *The Treatment of Infected Wounds*, 1917. University of London Press.

[2] BUNYAN, J., *Brit. Med. Jour.*, 1941, **2**, 1.

[3] MCKEE, G. K., *Lancet*, 1940, **2**, 38.

[4] HUDSON, R. VAUGHAN, *Brit. Med. Jour.*, 1941, **2**, 7.

[5] PEARSON, BRUCE, and HANNAY, J., *Ibid.*, 46.

CYSTS OF THE SPLEEN

By MILROY PAUL, Ceylon

Cysts of the spleen are rare. Only 4 cases of cyst of the spleen have been seen at the Mayo Clinic from 1904 to 1934 (Pemberton[1]). Fowler[2] (1940) was able to collect the records of 137 non-parasitic cysts of the spleen from the literature up to Jan. 1, 1939. The first cyst of the spleen to be recorded was that of Andral[3] in 1829. This cyst, discovered at a post-mortem examination, contained sebaceous material and hair, and these unusual findings present a pathological problem which is still unsolved. A sufficient number of cases of cysts of the spleen have now been recorded, and it is possible to draw some conclusions as to the different types of cysts which occur in the spleen. The classification put forward by Fowler (1940) is widely quoted, but it is not an entirely satisfactory one in that it is based on unproven views as to the aetiology of some of the cysts. There are, however, certain broad distinctions which serve to group the cysts into main types which would be readily recognizable by all workers, and these will be considered in this paper.

The *Echinococcus granulosus* is the only parasite giving rise to cysts in the spleen. Arce[4] (1941), of Buenos Aires, found the spleen affected by hydatid cysts in 3 per cent of his cases. He considers splenectomy to be the best treatment, as marsupialization is followed by a long-standing fistula leading to amyloid degeneration of the spleen, liver, and kidneys.

Multiple cysts of the spleen are occasionally seen in cases of polycystic disease of the kidneys, and such cysts, together with the multiple cysts of the liver and pancreas which are also sometimes encountered in this disease, present a problem which intensifies the difficulties to be faced in explaining the origin of the cysts of the kidneys. Indeed, no theory has yet been propounded which would satisfactorily account for cysts in all these viscera of such widely different structure and origin.

Of the other cysts of the spleen, classification is difficult in that many gradations of type are encountered, and intermediate types are not uncommon. These cysts fall into two main classes—large single cysts and multiple cysts. The single cysts may be associated with scattered small cysts, and the multiple cysts may be mainly made up of one or two very large cysts. The large single cyst is found in 80 per cent of the cases of non-parasitic splenic cysts (Fowler, 1940). These cysts are of three main types which shade one into the other. At one end of the scale is the dermoid cyst lined by stratified epithelium and containing sebaceous material and hair. Such cysts are excessively rare, and it is curious that the first cyst to be described was of this type. Gosset, Bertrand, and Gosset[5] (1939) were able to collect the records of only 4 such cases from the literature. The origin of these dermoid cysts is obscure. Epithelium and epithelial derivatives could not normally find a place in the spleen, developed as it is from mesodermic tissues, deeply situated well away from epithelial structures; and yet an epithelial cell inclusion is the only explanation of this type. At the other end of the scale are the cysts containing blood or altered blood, with a lining of connective tissue. Such cysts must have originated from intrasplenic hæmorrhages. In so friable an organ as the spleen such hæmorrhages could have arisen from trauma, infarction, or less commonly from intrasplenic softening produced by infections of the spleen pulp or degenerations of normal or abnormal splenic tissue. An enlarged malarial spleen would be more prone to undergo such changes, and a history of malaria would be of significance. Probably in this group are the single cysts containing serous fluid with a lining of connective tissue. Such serous cysts could have resulted from an old-standing intrasplenic hæmorrhage in which absorption of the blood-pigments and fibrin had occurred. Another explanation of these serous cysts is that the cysts are lymphatic cysts. This raises the vexed question of the presence of lymphatic vessels in the spleen. Ruysch[6] first described lymphatics in the capsule of the spleen, and he believed that lymph-vessels entered the interior of the spleen, while Baum[7] denied the existence of deep lymphatics in the spleen. These large cysts are occasionally associated with small isolated multiple cysts, and in such cases a lymphatic origin would appear to be more likely.

The multiple serous cysts of the spleen cannot be accounted for by the theory of intrasplenic hæmorrhages. The cysts have an endothelial lining. Some of them present the appearance of lymphangiectases. Indeed, the first case of this type was described by Fink[8] in 1885 as a case of multiple lymphangiomatous cysts of the spleen. Apart from lymphatic vessels, an endothelial lining could be derived from the endothelial cells of the spleen or from inclusions in the spleen of the investing peritoneal endothelium.

In an intermediate group between the dermoid cysts on the one hand and the blood-cysts on the other, are the epidermoid cysts. These cysts are distinguishable from the dermoids in that they contain neither sebaceous material nor hair. The walls have an incomplete lining of stratified epithelium. In places the wall is lined by fibrous tissue only and in others there is a lining of

endothelial cells. Contrasting with the dermoid cysts, an epithelial-cell inclusion is unlikely to account for the origin of these epidermoid cysts. It is more likely that the epidermoid lining has been derived by metaplasia from an endothelial lining. Even if the presence of lymphatics in the spleen be denied, endothelial cells are abundant in the spleen. Indeed, an epidermoid cyst could be derived from a blood-cyst which had acquired an endothelial lining that subsequently underwent metaplasis.

The epidermoid cysts and blood-cysts present similar macroscopical appearances. The cyst may affect any part of the spleen, and a well-recognized area of splenic tissue is generally recognizable at one or other pole of the cyst. The inner wall is trabeculated. The cyst contains a thin fluid, brown from admixture with blood, and glistening from its content of cholesterin crystals. Outside the incomplete cellular lining of the cyst is a layer of firm laminimated hyalinized fibrous tissue.

Classification of Cysts of the Spleen.—

1. Hydatid cysts of the spleen.
2. Multiple serous cysts associated with polycystic disease of the kidneys.
3. Single cysts :—
   a. Dermoid cysts.
   b. Epidermoid cysts.
   c. Serous and blood-cysts, devoid of an epithelial lining.
4. Multiple serous cysts.

Symptoms.—The large splenic cyst will cause symptoms from pressure. There will be a long latent period during which the cyst gradually reaches a sufficient size to cause pressure symptoms. A dull aching pain in the left hypochondrium is not uncommon. Other symptoms which have been noted have been variable and of little help in diagnosis. The patient might notice the large tumour in the left hypochondrium. On examination there is a round mass in the left hypochondrium, dull on percussion, lying close up against the anterior abdominal wall. An X-ray examination after a barium meal will demonstrate a displacement of the œsophagus and stomach to the right which is often extreme, and the downward displacement of the splenic flexure of the colon. Direct or indirect pyelography will demonstrate that the left kidney is normal.

The pre-operative diagnosis of a splenic cyst has rarely been made.

Treatment.—Treatment of splenic cysts by puncture, marsupialization, or by excision is unsatisfactory. Unless contra-indicated by dense adhesions, the method of choice is splenectomy.

CASE HISTORY

L. A. S., aged 19, female, single, was admitted to the General Hospital on Oct. 18, 1941, on account of a lump in the left upper abdomen. The lump had first been noted one year ago. It had gradually got larger. The lump had originally appeared coming from under the ribs on the left side. There was slight pain when the lump was first noted, but this had disappeared. The pain had reappeared again in the last three months. It was of an aching character, coming on once in three or four days and lasting two or three hours each time. It had no relation to the taking of food or to any particular time of the day. There was no nausea or vomiting.

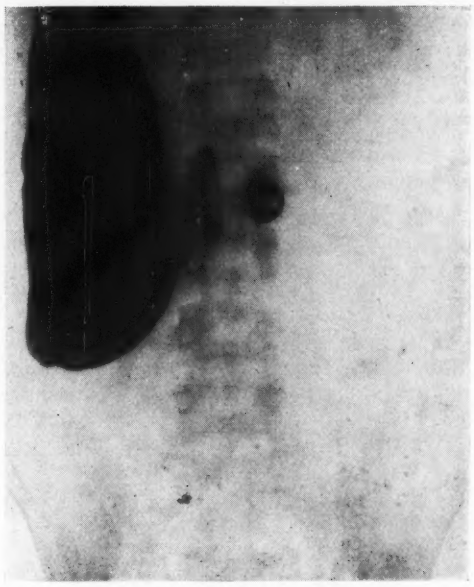

FIG. 357.—Radiograph immediately after the barium meal, showing the barium-filled stomach lying well over to the right, with a J curve at its lower end pointing to the left.

Two years ago she had had two or three attacks of malaria lasting about a month on each occasion. Menstrual periods were regular and painless.

ON EXAMINATION.—The patient was seen to be a well-nourished girl, conjunctivæ pink, tongue clean and moist, no œdema of extremities. There was a large swelling occupying the epigastric and left hypochondriac regions. The lump was intra-abdominal. It came from below the costal margin and reached down to the level of the umbilicus. It was immediately below the anterior abdominal wall. It had a sharp lower edge, its surface was smooth and round and its consistency soft. Fluctuation was obtained. It moved with respiration. On percussion a stony dull note was obtained over it. The dullness was continuous with an area of dullness under the left lower ribs. There was no shifting dullness in the flanks. The liver was not palpable below the right costal margin. Chest: Cardiac dullness and pulsation of apex beat to the left of the sternum.

X-ray Examination after Barium Meal.—Immediately after the meal: The stomach lies vertically, well to the right of the vertebral column, and there is a curve to the left at the lower end, suggesting that the pylorus lies to the left of the œsophageal opening (*Fig.* 357). Two hours after: The barium in the stomach has entered the small intestine. There is about one-third of the barium left in the stomach (*Fig.* 358). Five hours after: There is a small residue of barium left in the stomach. The barium has reached the colon. On the left side the colon is

filled with gas, and it was thought that this gas-filled bowel was the cæcum and ascending colon with descending colon on the right side (*Fig.* 359).

X-ray Examination of Chest.—The diaphragm is one rib higher on the right side, and the heart is placed normally with the apex towards the left.

It was considered that here was a case of transposition of the abdominal viscera with the liver lying to the left. The higher elevation of the diaphragm on the right side was, however, not consistent with this view. The lump was supposed to be a large cyst

FIG. 358.—Radiograph two hours after the barium meal.

FIG. 359.—Radiograph five hours after the barium meal; the colon on the left side contains gas.

of the liver, and it was decided to advise exploration.

Before this was done kidney and liver functions were investigated :—

Blood-urea: 23 mg. *Examination of stools*: fat +; undigested vegetable cells +; muscle-fibres nil; hookworm ova a few; round-worm ova a few. *Urine*: Albumin and sugar nil; diastase nil.

Blood :—

R.B.C.	46,20,000	
Hb	75	per cent
W.B.C.	6,200	
Differential count :		
Polymorphs	60	per cent
Lymphocytes	33	per cent
Eosinophils	7	per cent
Mononuclears	nil	

Liver Functions: Hippuric acid test, 76 per cent of normal function; icteric index 5; Van den Berg, direct and indirect and quantitative, negative; Takata-Ara test, negative.

AT OPERATION.—The patient was operated on Oct. 31 under spinal light percaine anæsthesia. A left paramedian incision extending from the xiphisternum to the umbilicus was made. A large cyst was seen immediately under the abdominal wall. The stomach was in the right hypochondrium, to the right of the cyst. The liver lay above the stomach, further to the right. The gall-bladder was normal. The cæcum and the appendix were on the right side. It was clear, therefore, that there was no transposition of viscera and that the cyst was in the spleen. There was a sharp edge of normal splenic tissue below the cyst. There were three cord-like adhesions between the spleen and the diaphragm, and these were ligatured. The cyst in the spleen occupied the whole of the left hypochondrium and the epigastrium. It had a thick white wall. The spleen was mobilized by division of the lienorenal ligament and splenectomy performed. The cyst contained a thin brown fluid with the glistening sheen of cholesterin crystals. Microscopical examination of the fluid showed red blood-cells and cholesterin crystals.

The patient made a good recovery from the operation and left hospital on Dec. 4.

THE SPECIMEN (*Figs.* 360, 361).—Dr. W. A. E. Karunaratne reported : "There is a large cyst in the spleen. The inferior edge of the spleen is well defined, as is also the posterior edge. The cyst bulges on the diaphragmatic surface of the spleen, and here the thick white wall of the cyst reaches the surface. The cyst also bulges on to the gastric surface of the spleen. The greater part of the cyst is covered by a thin layer of compressed splenic tissue. There are small cysts, the size of peas, in the wall of the main cyst. These small cysts are thin and translucent. The inner wall of the main cyst is trabeculated and white in colour.

"*Microscopical Examination of Cyst Wall.*—The section shows hyalinized fibrous tissue containing several cysts, lined by stratified epithelium (*Figs.* 362, 363). A few patches of calcification are also to be seen."

Commentary.—The case is clearly that of a solitary serous cyst of the spleen. The wall is lined by fibrous tissue, the patient gives a past history of

malarial fever, and the origin of the cyst from an old intrasplenic hæmorrhage seems likely. The pathological finding of microscopic cystic spaces lined by stratified epithelium in the laminated fibrous wall of the cyst is interesting. Here is a transition stage between the solitary serous cyst with a fibrous-tissue wall and multiple serous cysts, with the interesting variation of the main cyst having a fibrous-tissue wall, while the microscopic cysts have a stratified epithelial lining which is characteristic of the large epidermoid cysts.

The pre-operative diagnosis of transposition of abdominal viscera was based on the X-ray findings. The position of the stomach in the radiograph well to the right of the midline with its J curve to the left, suggested a transposition, as did the presence of the gas-filled large bowel on the left of the midline. Both appearances were misleading, as was shown by the operative findings.

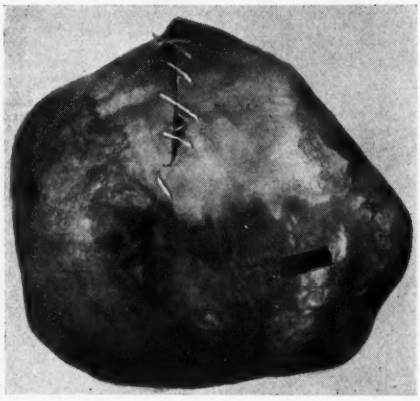

FIG. 360.—The spleen from the diaphragmatic surface. The spleen is considerably smaller than it was at the time of the operation. (⅓ *natural size.*)

FIG. 361.—The spleen from its inferior aspect. The bulging of the cyst on the gastric impression of the spleen is well shown. The spleen is considerably smaller than it was at the time of the operation. (⅓ *natural size.*)

FIG. 362.—A section showing several spaces lined by stratified epithelium in hyalinized fibrous tissue. To the right of the lowermost cyst is an area of angiomatous tissue. The lumina of the cysts show varying amounts of a homogeneous eosinophilic material. (× 160.)

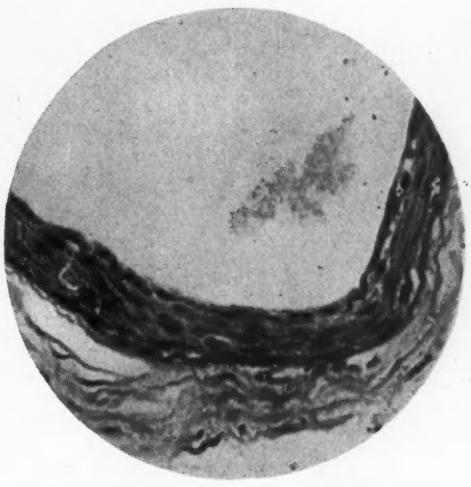

FIG. 363.—A higher power view of a portion of *Fig.* 362, to show the stratification of the epithelial lining. (× 800.)

REFERENCES

[1] PEMBERTON, J. DE J., and ROBERTSON, F., ' Solitary Cysts of the Spleen ', 1940, **3**, 848.

[2] FOWLER, R. H., *Internat. Abstr. Surg.*, 1940, March, 213.

[3] ANDRAL, *Abdominal Operations* (Moynihan), 1914, **2**, 447. W. B. Saunders Co.

[4] ARCE, JOSE, *Arch. of Surg.*, 1941, **43**, No. 5, 789.

[5] GOSSET, A., BERTRAND, I., and GOSSET, J., *Jour. de Chir.*, 1939, **54**, 289, quoted in *Internat. Abstr. Surg.*, 1940, Feb., 144.

[6] RUYSCH, quoted by FOWLER.

[7] BAUM, quoted by FOWLER.

[8] FINK, quoted by FOWLER.

EXCISION OF THE ŒSOPHAGUS FOR MALIGNANT GROWTH BY THE ABDOMINO-CERVICAL ROUTE

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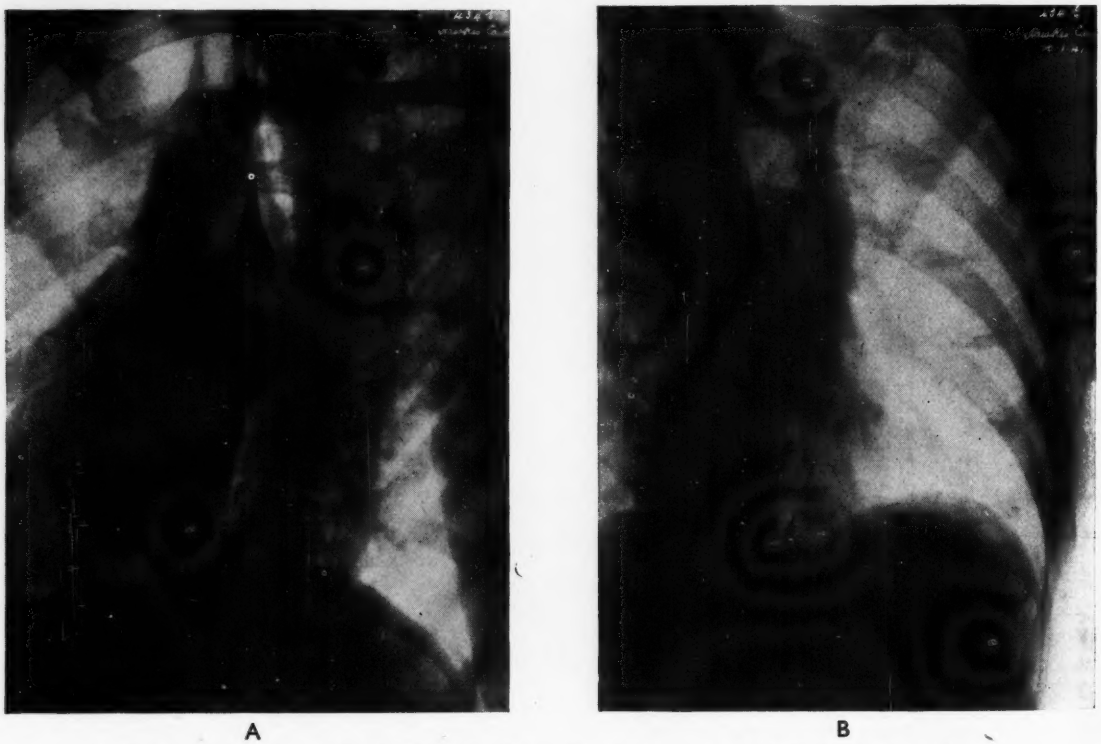
THE abdomino-cervical route for the excision of the œsophagus was first described by Professor Grey Turner, and details of 2 successful cases are here recorded, together with notes on 4 cases in which the operation was not feasible.

CASE REPORTS

Case 1.—Mrs. C. H., aged 55, was admitted to the Kingston County Hospital on Jan. 17, 1941. She was a thin woman, who gave a history of eight weeks' dysphagia; she could only swallow fluids when admitted. She had had no pain. She had undergone an operation twenty-eight years previously for removal of a "tumour of the stomach". A barium swallow showed a constriction at the level of the 9th dorsal vertebra (*Fig.* 364, A, B). On Jan. 24 an œsophagoscopy was performed and a stricture found 12 in. from the alveolar margin. The obstruction bled easily, and a small piece was taken for section, but was not satisfactory and was reported as normal epithelium. In view of the clinical picture exploration was decided upon.



A B

FIG. 364.—*Case* 1. Barium swallow, showing malignant stricture at level of 9th dorsal vertebra.

OPERATION (Jan. 29, 1941).—Under evipan, gas, oxygen, and ether anæsthesia from a Boyle's apparatus given by Dr. Allen and supplemented by local injection of 2 per cent novocain, an incision was made along the anterior border of the left sternomastoid and the œsophagus freed so that a tape could be passed round it. This dissection was helped by the passage of a stomach tube. The abdomen was then opened by a long median incision commencing at the xiphisternum. The left lobe of the liver was mobilized and also the lower end of the œsophagus. One gland was found and removed. By working simultaneously from above and below and using finger dissection, the œsophagus was mobilized on its posterior and left lateral aspects. As the growth was mobilized a small tear was made in the left pleural sac, but this caused little trouble as the inrush of air was easily controlled. Care was taken to avoid mobilizing the œsophagus on the right side near the vena azygos. A stout gum-elastic catheter was then passed from the cervical incision down to the stomach, parallel with the œsophagus, and the œsophagus cut across just proximal to the stomach and ligatured with stout silk, one end of which was passed through the end of the catheter. The cut end was carbolized and traction made on the catheter. By gentle traction and guidance from the left forefinger

in the mediastinum the œsophagus was delivered through the upper wound. The cardiac orifice was then closed and a Lepage-Janeway gastrostomy performed, the gastric tubed pedicle being brought out just above the costal margin through a stab incision. There were no other enlarged glands or secondaries. After removal of the growth and 6 in. of œsophagus, the proximal end of the œsophagus was sutured to the

FIG. 365.—*Case* 1. Photograph taken December, 1941, showing anterior thoracic œsophagus reconstructed as far as gastrostomy opening.

margins of a stab incision at the level of the third rib, and the cervical wound closed. A drip transfusion was used throughout the operation. but hæmorrhage and shock were slight, the pulse-rate being 120 at the commencement of the operation and 118 at the end. The operation lasted 2 hr. 15 min.

Convalescence was uneventful, but considerable difficulty was found in controlling leakage from the upper end. Excellent upper and lower special fittings of moulded rubber were made by the dental surgeon, Mr. Arthur Bell, and connected by a rubber tube. The specimen showed a carcinoma of the œsophagus 1½ in. long, and Professor Barnard reported it to be a squamous-celled carcinoma with a number of cell-nests. The gland also showed the presence of a secondary deposit. The patient was discharged on March 15, 1941.

On June 6 she was readmitted to have an anterior thoracic œsophagus constructed from skin. This was attempted by making two parallel incisions 2½ in. apart, from just below the upper opening to 1 in. above the gastric opening, and tubing the flap so constructed. The raw surface was covered by undercutting of the skin lateral to the incisions, and direct approximation, so burying the tube.

The wound healed fairly well, and on June 25 the upper end was closed over an œsophageal tube. This was only partially successful, and there were two fistulas through which saliva leaked. Several further attempts were made to close these, including resection of the inner third of the clavicle, but were unsuccessful. Mr. Pomfret Kilner finally saw the case and advised that a small tubed pedicle graft be fashioned to close the opening. This was done, and later he successfully closed the fistula. Trouble was caused by scar tissue causing a stricture at the mucocutaneous junction, and this had to be dilated. The patient gained weight, from 5 st. 12 lb. in June to 6 st. 2 lb. in December, but was troubled with attacks of diarrhœa which were accompanied by pyrexia (*Fig.* 365). These gradually became more frequent and her general condition deteriorated. On Dec. 12 she started to have auricular fibrillation which was controlled by digitalis. On Jan. 9, 1942, under local anæsthesia, Mr. Kilner cut a delayed flap around the gastrostomy opening. Radiography of the chest showed no evidence of secondary deposits, but the patient developed a cough and went gradually downhill, dying from bronchopneumonia and auricular fibrillation on Feb. 10, fourteen months after the first operation.

POST-MORTEM EXAMINATION.—This showed the posterior mediastinum to be closed by dense fibrous adhesions. Three pieces were taken for section and also a small gland. Dr. S. Popjak reported sections 1, 2, and 3 to have strands and small islets of squamous-celled carcinoma in large amounts of fibrous tissue. The gland showed fibrosis only. No other secondaries were present, death being due to bronchopneumonia and myocardial degeneration.

Case 2.—Mr. F. S., aged 67, was admitted to the Kingston County Hospital on June 8, 1941. He complained of difficulty in swallowing for six months, and had been treated at a London hospital by dilatation. This improved his dysphagia, but four days previous to his admission he could only swallow liquids with difficulty. He had no pain, but had lost a considerable amount of weight. A barium swallow showed an irregular stenosis of the œsophagus at the junction of the middle and lower third (*Fig.* 366), and œsophagoscopy by Mr. Mill revealed the presence of a subepithelial carcinoma 38 cm. from the alveolar margin. Biopsy confirmed the diagnosis.

OPERATION (June 26).—Under gas, oxygen, and ether the thoracic œsophagus and growth were removed by the same technique as before, but a Kader-Senn gastrostomy was performed. In freeing the upper end of the œsophagus the inferior thyroid artery had to be divided (this was probably the cause of the sloughing of the proximal end of the œsophagus). The gastric artery was ligatured and the glands on the lesser curvature removed as they were enlarged. The specimen showed a carcinomatous stricture 2 in. long, with 5 in. of normal œsophagus proximal and 2 in. distal to it, together with some glands in the gastro-hepatic omentum. A blood transfusion was given during the operation, which was accomplished without any trouble from hæmorrhage or shock.

Convalescence was smooth, and Mr. Arthur Bell devised special fittings for the fistulæ so that normal swallowing could be allowed. The patient was discharged from hospital on July 30, 1941.

He was readmitted on Aug. 19 because of difficulty in getting proper food. Owing to some sloughing of the upper end of the œsophagus stricture formation was a source of trouble. An attempt to make a skin œsophagus, as in the first case, was unsuccessful owing to infection. Mr. Pomfret Kilner raised a tubed pedicle flap running from the right shoulder

towards the gastrostomy opening, and this was lengthened by stages. Parallel incisions between the two fistulæ enabled a skin tube to be fashioned, the raw area being covered by the opened-out pedicle graft. This ensured suturing without tension and avoided the suture lines being superimposed. (*Fig.* 367.) The transplantation was done in stages, but as the original tubed pedicle graft was not long enough to cover in the gastrostomy opening a pedicle graft was raised from the abdomen. This operation was

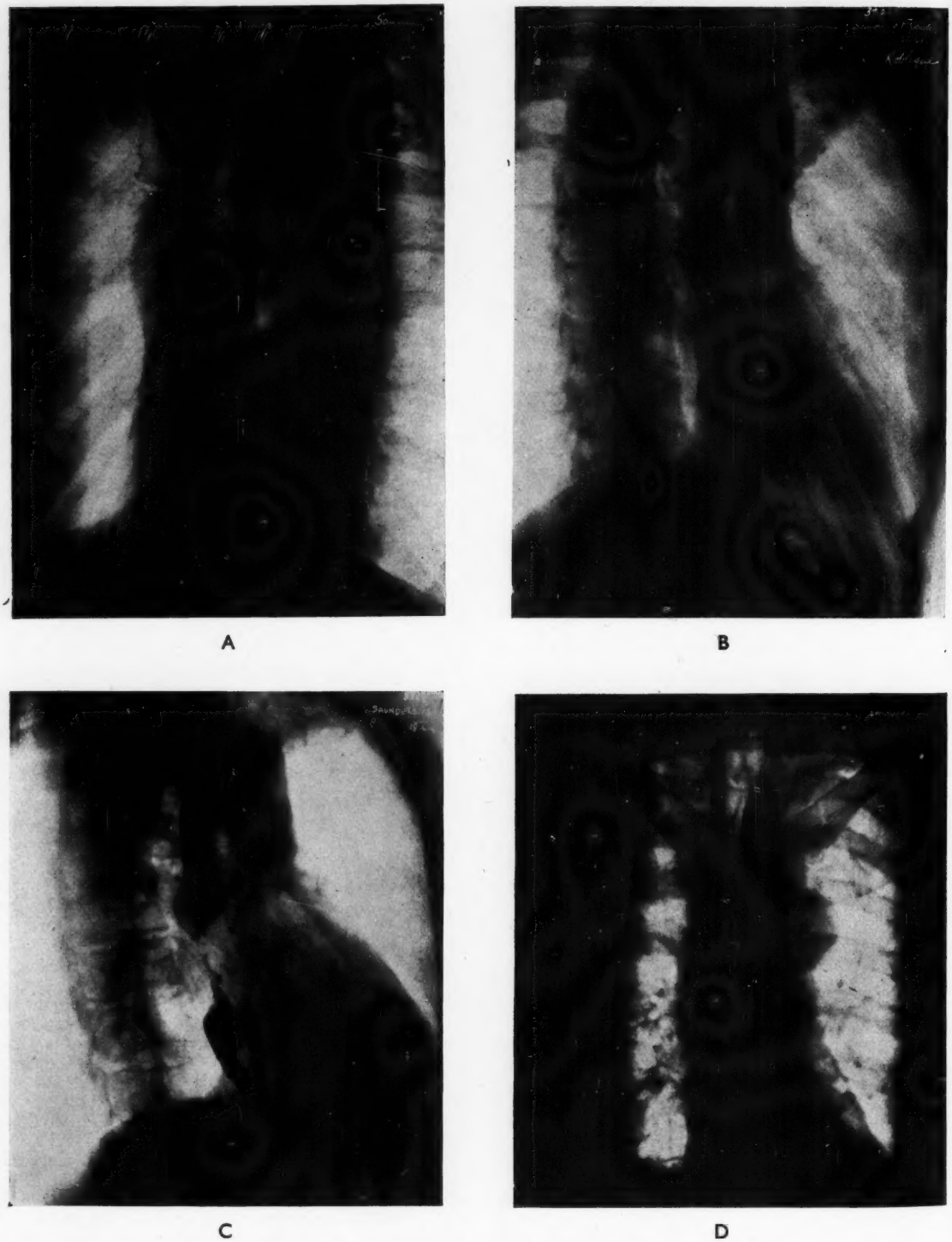


FIG. 366.—*Case* 2. Radiographs following a barium swallow, showing malignant stricture at level of 9th dorsal vertebra.

performed on July 8, 1942, under local anæsthesia, but it was followed by retention of urine which necessitated catheterization. Some cystitis ensued and was followed by a severe attack of diarrhœa, in which blood and mucus were passed. His condition rapidly

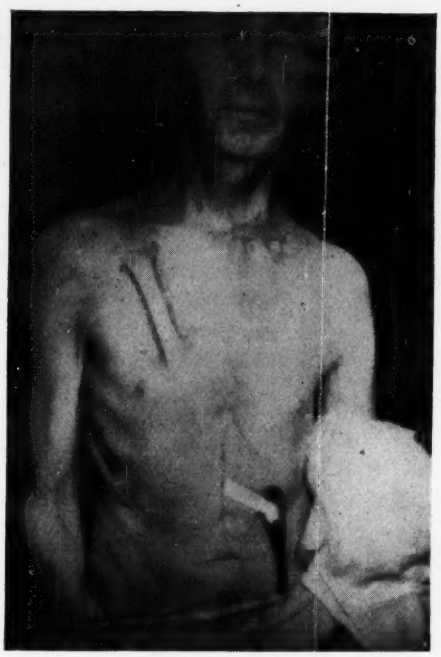


FIG. 367.—*Case* 2. Photograph taken December, 1941, showing first stage of tubed pedicle flap and œsophageal fistula at level of 3rd costal cartilage and gastrostomy opening.

deteriorated, and he died on Aug 8, fourteen months after the first operation. The weight improved after the gastrostomy and remained stationary at about 7 st. 6 lb.

Autopsy showed no evidence of recurrence, and death was due to myocardial degeneration following cystitis and enteritis.

2. Mr. H. M., aged 62. History of 7 to 8 weeks' pain in the chest and dysphagia. Some loss of weight. May 5, 1942, œsophagoscopy—growth on posterior wall 27 cm. from the alveolar margin. May 12, operation under general anæsthesia. Cervical and abdominal incisions and upper and lower end of the œsophagus mobilized. Growth infiltrating structures in the posterior mediastinum. Gastrostomy. Patient discharged on June 2.

3. Mr. J. L., aged 56. Loss of weight and dysphagia for 3 to 4 months. No pain. June 24, 1942, œsophagoscopy. Stricture 22 cm. from alveolar margin. Squamous-celled carcinoma. July 7, under general anæsthesia œsophagus explored from the neck. Growth 2½ in. long infiltrating the trachea. Gastrostomy. Patient discharged on July 29.

4. Mr. C. C., aged 67. Dysphagia and loss of weight for two months. Pain in right side. Nov. 4, 1942, œsophagoscopy. Stricture 19 cm. from alveolar margin. Pathological report shows squamous-celled carcinoma. Nov. 9, operation. Cervical incision, hard fixed mass found at the level tof he second dorsal vertebra. Gastrostomy. Satisfactory progress.

DISCUSSION

The abdomino-cervical route is suitable for carcinoma of the œsophagus occurring in the lower third, or in the more uncommon situation proximal to the arch of the aorta. While it may be criticized as a ' blind ' operation, it does allow of a resection of the lymphatic drainage area along the lesser curvature of the stomach. It has the further advantage that there is less shock than when the thorax is opened, and no special complications are likely to ensue. If the growth is found to be inoperable it is possible to abandon the operation and perform a gastrostomy. It is, however, true that a few cases which might be considered to be inoperable by this approach might be amenable to more radical surgery after thoracotomy. Such cases as require extensive dissection are more likely to give rise to recurrences.

ADAPTED GASTROSTOMY DIET NO. 3

	CARBOHYDRATE	PROTEIN	FAT	CALCIUM	PHOSPHATE
	g.	g.	g.	g.	g.
Ostermilk, 5 oz.	55	35	40	1·393	1·162
Milk, 40 oz.	60	40	48	1·140	1·116
Egg, 1	—	6	5	·042	·130
Margarine, 1 oz.	—	—	25	·005	—
Marmite, 1 teaspoonful	—	—	—	—	—
Sugar or Glucose, 1 oz.	30	—	—	—	—
Halibut-liver oil, 9 drops	—	—	—	—	—
Salt, 1 teaspoonful	—	—	—	—	—
Mist. Ferri et Ammon Cit., gr. 90	—	—	—	—	—
Ascorbic acid, 1000 mg.	—	—	—	—	—
Give 6 10-oz. feeds					
1966 calories	145	81	118	2·580	2·408

CASES EXPLORED

1. Mr. J. N., aged 69. Squamous-celled carcinoma. Growth 18 cm. from alveolar margin on anterior wall of œsophagus. May 19, 1942, preliminary gastrostomy (Kader-Senn) owing to poor condition. June 27, œsophagus exposed in neck. Extensive growth adherent to trachea. Died on July 31.

Both cases had a terminal diarrhœa of considerable severity, and bacteriological investigations failed to reveal any special organism. The diet tabulated above was given.

It would seem probable, however, that lack of saliva and loss of appetite, with defective gastric secretion, may be the factors responsible

for the diarrhœa. It is therefore important to connect the upper and lower fistulæ as soon as is possible, by a plastic operation. The technique of this repair requires further thought and experiment, and the assistance of a specialist in plastic surgery is of the greatest value. All the plastic operations were done under local anæsthesia.

SUMMARY

1. Two cases of carcinoma of the lower third of the œsophagus were treated by œsophagectomy by the abdomino-cervical route.

2. The technique of the operation is described.

3. Both cases lived for over a year. One had no recurrences, and in the other they were localized to a small area of the mediastinum.

4. Both were troubled with diarrhœa, which caused the death of the second case.

No surgeon could have wished for more helpful or co-operative patients.

I wish to express my thanks to Professor Grey Turner for the encouragement he has given me and for the interest he showed in the cases.

I am deeply indebted to Mr. Pomfret Kilner, whose patience and skill in carrying out some of the plastic surgery have been invaluable.

I am grateful to Mr. Jennings Marshall for the photographs, and to my Assistants and Nursing Staff for their unfailing care and attention.

REFERENCE

[1] TURNER, G. GREY, *Lancet*, 1933, **2**, 1315.

FIBROUS STRICTURE OF THE GULLET OF NINETEEN YEARS' DURATION

Feeding by extrathoracic rubber œsophagus throughout the greater part of that time. Restoration of normal swallowing by bouginage. Closure of gastrostomy and œsophagostomy.

BY G. GREY TURNER

THE case related is that of an intelligent young medical man (R. S. W.), twenty-six years of age, who came under my care on account of intractable stomach pain associated with a gastrostomy of nineteen years' standing. He was the victim of stricture of the gullet following the swallowing of caustic soda; this disability had resisted all attempts at dilatation and the œsophagus was considered to be obliterated at the injured site. It was for this condition that the gastrostomy had been made, and later, as a stage in an attempt to construct an extrathoracic œsophagus, a cervical œsophagostomy. These attempts at œsophagoplasty had failed and it was necessary to fall back on the use of a rubber tube connecting the cervical fistula with the gastrostomy. Swallowing by means of this apparatus was satisfactory and the patient had been able to lead a normal life, to complete his education, and to graduate. When he came under my care he had for long accepted the artificial œsophagus as inevitable and permanent, and his only thought was to get rid of the stomach pain. The following detailed history was written by the patient himself.

"I had always been a healthy child, suffering only from measles; the tonsils had been removed. On Aug. 1, 1922, when aged seven years, I swallowed some two mouthfuls of commercial caustic soda solution which I believe had been slightly diluted. First-aid treatment by administration of vinegar and olive oil was carried out by my parents and the doctor was sent for. On his arrival I was put to bed and treated for shock from which I suffered severely for some two or three days. My mouth and throat were badly burned by the caustic, but I quickly recovered and was sent to stay with friends in the country, and it was while there, some three weeks after the accident, that I first experienced difficulty in swallowing. My parents were sent for and I was taken to see a surgeon who diagnosed stricture of the gullet. Since my home was in a big city I was referred to a surgeon resident there, who suggested gastrostomy. At that time my parents refused to agree, but I was subsequently admitted to the infirmary for treatment. The condition was again investigated and attempts were made to pass bougies both with and without anæsthesia, but without success. Gastrostomy was again suggested; but I suppose my parents must have refused, because I was discharged without improvement. Dysphagia was becoming increasingly more marked, and I now swallowed even milk pudding with difficulty.

"I was then seen by one of the surgeons to the Ear, Nose, and Throat department, who at first considered the dysphagia to be neurotic in origin. This, I think, was because I could swallow a fair amount of fluid, which filled up my gullet proximal to the stricture before regurgitating. However, I was treated as a query neurotic for some time, and exhorted, encouraged, and threatened alternately. It soon became obvious that something a little more finite was amiss. The throat surgeon then tried bougies, but after several attempts pronounced this treatment to be hopeless and suggested gastrostomy, which was again declined. Swallowing was now very difficult, and even fluids could only be got over with much trouble. A clergyman friend of my father's asked if he might bring a homœopathic practitioner to see me. This gentleman duly arrived, and I was admitted to another hospital. By this

time I could hardly swallow my saliva and was becoming noticeably starved. Again treatment was unsuccessful, and finally, in September of 1922, gastrostomy became inevitable and was carried out as a life-saving measure. While under the anæsthetic bougies were again tried, but without success. I remained in the hospital for some time but failed to improve even after the operation had made feeding possible, and so I was taken home by my parents.

"I had by this time become extremely emaciated and even at home I did not thrive well and developed gastric pain and most intractable constipation. It should be stated that after the gastrostomy and before the extrathoracic œsophagus was devised, all my saliva had to be expectorated. It was then suggested that I should chew my food before passing it (sieved) into my stomach (per gastrostomy) and this seemed to help immensely, for I quickly began to improve thereafter and by July, 1923, I was again in good general health although quite unable to swallow. I resumed school in August, 1923.

"About this time my father chanced to read in the local paper of Rovsing's successful creation of an antethoracic œsophagus. He at once asked for further details, and got in touch with the Professor, and as a result I sailed for Copenhagen with my mother and arrived there in October, 1923.* Investigation by bougie and X rays demonstrated what was regarded as an obliteration of the œsophagus opposite the seventh costal cartilage. I remained in Professor Rovsing's Clinic for several months, during which time the following operations were performed: (1) Formation of cervical œsophageal fistula; (2) Enlargement of gastrostomy; (3) Several, I think at least half-a-dozen, attempts to form an antethoracic œsophagus. The skin of my chest proving too delicate, grafts were taken from the anterior surfaces of both my thighs, but in spite of this reinforcement the skin-tube always broke down. During this time I wore a tube in the cervical fistula which drained into a bottle, feeding being entirely by the gastrostomy. All attempts having failed, after a stay of 18 months, I returned home in April, 1925, with the suggestion that I should return to Copenhagen when older, when a further effort to construct a gullet would be made.

"My father then conceived the idea of connecting the tube leading from my œsophageal fistula in the neck to that from my gastrostomy,† thus producing an antethoracic œsophagus of rubber tubing. By great perseverance this was eventually accomplished. At first I could only swallow fluids and with difficulty. but the openings were gradually dilated so that larger bored tubing† could be used, and within a year and a half of the beginning of this experiment, i.e., at the end of 1927, I was able to swallow all my food by this extrathoracic device and completely dispensed with gastrostomy feeding. The cervical œsophageal tube was renewed some six to eight times each year, and that of the gastrostomy about four or five times. Using this apparatus I swallowed every kind of food, and at a rate equal to that of the average individual, and have done so since about 1927. I always liked to have water by me and usually drank some during eating, but swallowing did not depend upon washing down my food. From time to time at all meals I almost unconsciously manipulated the tube by compressing it against my chest wall with my fingers from above down through my clothing, in that way producing a sort of artificial peristalsis, but almost certainly the main propulsion was by the pharyngeal muscles. With the aid of this home-made apparatus I have lived a full and unrestricted life and carried on my medical course side by side with my fellow students. I played soccer and golf and was fond of swimming. All my activities were carried out with the rubber tube in situ and neither my friends nor my teachers were aware of the condition.

"The illness which brought me to Hammersmith Hospital commenced somewhat as follows: In October, 1936, when in my third year of medical study, after a routine change of gastrostomy tube, I first suffered from an attack of sickness and anorexia of about ten days' duration. Treatment by alkalis cleared up the condition and my health returned to normal, but about a year later, again after a routine tube change, I suffered from the same symptoms. From time to time thereafter there were recurrences, particularly precipitated by exercise even of the mildest nature. Examination at this time revealed hyperacidity, but was otherwise negative. Alkali treatment alone failed to improve the condition and finally I had to spend some three weeks resting in bed and taking alkalis and a modified gastric-ulcer diet. Again my symptoms completely cleared up and I resumed normal health and activities. In August, 1938, I suffered from a recurrence which came on after a change of gastrostomy tube, though, of course, there had been several intervening changes since that of the previous December. I again retired to bed, but the condition was much more intractable and I spent six weeks recumbent and only got up to resume classes, for though my condition was much improved, it had not wholly cleared up. Believing my symptoms to be due to the irritation caused by the internal flange of the gastrostomy tube, I dispensed with this and used plain rubber tubing. My condition greatly improved and for a time I enjoyed good health, but after about six weeks I again had gastric upset. But the symptoms had changed so that epigastric pain about two hours after a meal was the outstanding feature. I considered this to be due to the fact that the gastrostomy tube was inserted too far into the stomach and in consequence was traumatizing the mucosa of the posterior wall. The tube was in a distance of 2½ in. from the skin surface, and although I withdrew it until the total length was only 1½ in. the pain persisted. As being easier to retain, I reverted to a flanged type of tube and suffered my previous symptoms of nausea. Examination by X rays was carried out. The opaque material was given by the mouth and at once passed into the œsophagus where it was completely arrested at the site of the stenosis. After filling the gullet there was an overflow into the rubber tube and so on to the stomach, where an ulcer on the posterior wall near the lesser curve was demonstrated. I was also examined in the Trendelenburg position, but the opaque material did not enter the œsophagus. A further six weeks were spent in bed on a strict gastric-ulcer régime, and further X-ray examination after two months showed no radiological evidence of the ulcer. I was now ambulant again, but my symptoms persisted in spite of dieting, medicinal treatment, and the introduction of flangeless tubes of softer rubber. I continued thus during the greater part of 1939 and was unable to attend classes. I did resume studies in October of that year, but after three weeks I was forced to give up since all my symptoms became

* Rovsing's first case was published in the Danish journal, *Hospitalstidende*, in January, 1923 (**66**, 1).

† The diameter of the tubes finally used was $\frac{7}{8}$ in. for the cervical fistula and $\frac{7}{12}$ in. for the gastrostomy.

greatly aggravated by continual standing in the wards and the exertion of travelling. I returned to bed and remained there until the following January. After getting up I had nearly all my teeth removed, as they were considered to be a source of possible infection. My condition was now completely relieved and I resumed classes at the beginning of February, but continued to be careful with food. I continued well until the beginning of September, 1940, and was about to sit for my final examination when the symptoms returned. At first I noted only anorexia, then some epigastric discomfort, and then nausea and vomiting. Again my symptoms were precipitated by exertion or exercise, even of the mildest nature; even standing for any length of time was sufficient to initiate an attack of violent sickness and vomiting. Hyperacidity persisted and the radiograph showed spasticity about the mid-gastric region with some five-hour residue. I considered, or perhaps really hoped against hope, that this recurrence was due to the strain of my examination, for I had worked very hard and consistently since resuming in February because I had been off ill for a full year and had much leeway to make up. But even though I did succeed in passing my finals my condition became progressively worse. I spent a further three weeks in bed, but though while resting my symptoms cleared up, whenever I tried to get up and about they returned, and it was for this reason that I was admitted to Hammersmith Hospital on Dec. 29, 1940."

On admission the patient was found to be a tall, slightly built young man of nervous expression. His main complaint was of the almost continuous gastric discomfort amounting to pain when the stomach was empty and only sometimes relieved by taking small quantities of food. He had frequent nausea, often lasting three days on end, and bouts of severe vomiting which occurred through the gastrostomy and up by the rubber tube into the mouth. In spite of all his troubles he was in fair condition and was most alert and interested. His weight at this time was 9 st. 2 lb., and height 5 ft. 10½ in. The artificial œsophagus functioned very satisfactorily. The patient could drink freely in the recumbent position, but preferred to be sitting when solids were taken. There was just the slightest hesitation with the first one or two mouthfuls, but once these were over swallowing was easy. *The local condition* with the tube in situ is well shown in the photograph (*Fig.* 368). In order to keep the lower end of the tube in position in the stomach and to support the bulging gastrostomy area the waist-band was kept fairly tight. When the rubber œsophagus was in position the margins of the gastrostomy and the cervical fistula were entirely covered. With the tube removed the appearances were as depicted in *Fig.* 369, which shows the large gastrostomy and the cervical fistula. Both these fistulæ easily admitted a thumb. The gastrostomy was represented by a direct opening into the stomach about an inch in diameter and without any valvular arrangement, the mucous membrane being continuous with the skin margin and prolapsed at the lower part. The gastric mucosa overlapped the skin margin and looked very angry and easily bled. When the patient stood up or coughed there was considerable bulging of the whole area and the prolapse of mucous membrane became much worse. The œsophagostomy, as shown in the illustration, was an opening that would also admit the thumb, but the skin edges shelved inwards towards it so that it lay at the bottom of a shallow funnel and the mucous membrane was not apparent. The skin lining this funnel was thin, bluish, and looked of poor nutrition, but it had not become excoriated. The chest wall between these two orifices and over an area 4 in. wide was universally scarred as the result of the numerous efforts to construct a dermal tube. In two places small bridges of integument had persisted, representing the only areas where the attempts had been even partially successful. In other parts the remains of whole-thickness grafts taken from the front of the thighs were obvious (*see Fig.* 372). Everything taken by mouth and the saliva overflowed from the œsophagus and then traversed the rubber tube to the stomach. This was known by the sensations of the patient who always felt that the food came up against a blockage before overflowing, and was confirmed by the radiograph after an opaque drink (*Fig.* 370). Detailed radiological examination of the œsophagus showed "A stricture commencing at about the level of the 7th dorsal vertebra and extending over a wide area. The œsophageal outline in this region is irregular, but the gullet proximal is rather constricted. The œsophageal stenosis is absolute". Through the gastroscope introduced via the gastrostomy the cardia was seen to be congested and œdematous, and a small

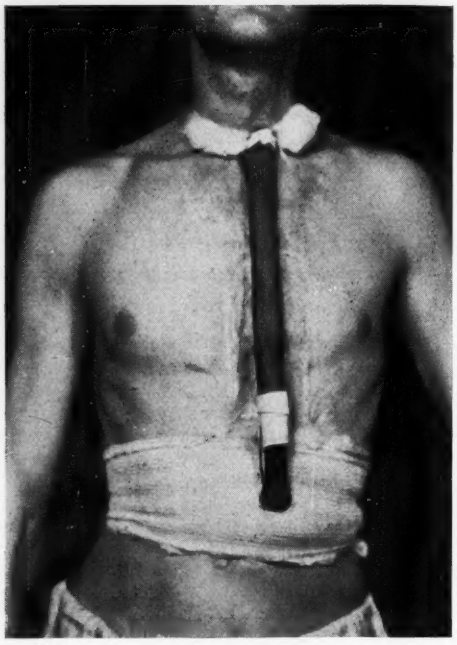


FIG. 368.—Extrathoracic rubber œsophagus in situ.

bougie could only be passed retrograde for a distance of ¾ in. into the œsophagus.

FIG. 369.—The œsophageal and gastric fistulæ.

In the management of the case attention was at first entirely focused on the stomach pain and its cause. The possibilities appeared to have been carefully explored by the patient and his advisers. Examination with the finger in the gastrostomy opening merely demonstrated the wide attachment of the stomach to the large parietal opening. No ulceration was seen either by the X rays or the gastroscope, but the mucous membrane just within the upper part of the opening and along the lesser curve was much reddened and there was an excess of mucus. There was also a tendency to mid-gastric spasm. The fact that the patient seemed to have done everything to overcome all removable causes of mechanical irritation without relief made me think of the possibility of some chemical irritant released from the rubber as the result of its long contact with the gastric secretions. But before this avenue could be explored a new chapter of hopeful possibilities opened for this patient. He had placed himself under my care solely because the gastric condition had defeated all efforts that had been made for its cure, and the most that he hoped for was to be restored to a condition in which the artificial œsophagus would be allowed to function unimpeded. There was just a hankering hope that it might yet be possible to construct a living antethoracic œsophagus, but the scarred condition of the skin of the chest wall rendered that highly improbable. Up to this time the obstruction in the œsophagus had always been looked upon as a complete fibrous obliteration. Having had previous experience of similar unpromising cases in which a tiny mucous-lined track was evidently hidden among scar tissue, I thought it fair to suggest to the

FIG. 370.—Radiograph showing complete arrest of the opaque material in the lower part of the thoracic œsophagus; also the extrathoracic rubber gullet.

patient that this might exist, and that in spite of so many disappointments a further attempt at treatment by bougies was worth a trial.

After reading some of my papers on œsophageal stricture in which some unpromising cases treated with sucess are recorded, the patient was keen that an attempt should be made and gave us his enthusiastic co-operation and support, which never flagged or became dismayed. *The method of treatment* proposed does not consist in *passing* bougies through a reluctant stricture, but aims at assisting the *swallowing* of bougies by the patient with some persuasive assistance after they engage. The story of my introduction to this method and the details of its application are fully related in a paper on "Non-malignant Stenosis of the Œsophagus"[1]. But in dealing with such strictures the resources of the surgeon are not confined to the use of bougies from the mouth, and the possibilities of relief by other means were brought to the notice of the patient. From the outset our efforts were more successful than appeared likely. In carrying out the treatment the enthusiastic co-operation of the patient supplemented the skilled assistance of Mr. R. H. Franklin and the devotion of Sister Mathias. At the outset we were prepared to have to fall back on a ureteric catheter to act as a ferret, but on the first attempt Mr. Franklin found that No. 6 œsophageal bougie (4 millimetres in diameter)* traversed the œsophagus down to a point 17 in. from the teeth, the last part of its journey seeming to encounter some resistance as though it had entered a strictured area, but though three lengthy attempts were made the bougie did not pass beyond the narrowing. The long distance from the teeth which the bougie was able to reach was almost certainly due to the instrument being very much bent or partly coiled in the œsophagus. Further, in these long-standing stricture cases the œsophagus becomes elongated. At the same sitting an attempt was made to guide a No. 13 bougie via the gastrostomy into the cardia, but without success. After withdrawal of the bougie and clamping of the tube from the œsophageal fistula the patient tried to swallow a glass of milk and experienced œsophageal distension which gradually relaxed on stopping the drinking. He felt the coldness of the milk and experienced pain and tenseness at the point of the stricture. But he was able to drink about 5 oz. and then the bougie was passed again to the same length as before, after which small flakes of milk were seen coming out of the gastrostomy wound, together with large quantities of mucus followed by gastric secretion.

From this time bougies continued to be used daily, but it was nearly a week before the next size larger negotiated the narrowed area. At that time a screen examination showed the instrument lying in the stricture, and two days later by means of the gastroscope bougie No. 7 was seen projecting 1½ in. into the stomach. The word 'used' is employed advisedly, for there was no occasion at this stage when a bougie could be 'passed' with intention through the stricture. By this time the patient himself was using the bougies and he sometimes spent an hour or more before the instrument discovered the route, and then by gentle assistance by pushing it was made to traverse the stricture. Some days were better than others. Once or twice the attempt had to be abandoned, but quite often on the succeeding day the instrument found its way with ease. Although the patient spent hours in attempts, it was with much difficulty that No. 8 could be got through. Usually there was some pain at the site of the obstruction and while the instrument was passing through the narrowed part. Occasionally the œsophagus rebelled and the patient would be conscious of an antiperistaltic wave and the part of the bougie in the mouth would be thrown against the palate. After withdrawing the instrument the patient could swallow fluids, but only slowly—11 oz. took fifteen minutes—and with some pain. But improvement was steady and by the end of three weeks No. 9 had passed and there was less pain or tendency to antiperistalsis.

The next stage in the management consisted in leaving the bougie in situ for increasing periods. Up till this time the instruments had been passed by the mouth, but on Jan. 29, after preparing the way by a No. 7 left in for an hour, No. 8 was introduced, this time through the cervical fistula, and was left in situ all night without causing the patient inconvenience. Next day No. 9 passed easily and was left in situ for six hours, and thereafter No. 10 passed with tolerable ease. But the advantage so gained was not easily maintained, and on Feb. 6 bougies were passed by the retrograde route in the hope of preparing the way for larger instruments. This was done without anæsthesia. As a first step No. 13 bougie was passed by the patient through the œsophageal fistula and attempts were made to recover this from the stomach using the finger and turning the patient over on his right side. This failed and the bougie was withdrawn and replaced by a No. 8 which went through more readily and the end of which we managed to hook out of the stomach, but only with some difficulty. A soft rubber tube was slipped over the end of this bougie and tied with linen thread; the instrument was then withdrawn, carrying after it the rubber tube which passed easily up the œsophagus. An attempt was made to draw up a still larger tube, but this failed. No. 13 bougie was now fixed into the lower end of the rubber tube, tied in position, and by combined gentle pushing from below and traction from above it was passed right up the œsophagus and out of the cervical fistula. A thread was tied to the lower end of the bougie, the other end of the thread being tied to a piece of gauze and the bougie drawn a little farther up so that the lower butt end lay free in the stomach. While the instrument was in position he complained of some pain in

* The bougies used are designated by the standard English gauge.

the stomach, which was relieved by belladonna; there was also slight discomfort throughout the œsophagus. As this plan proved successful, we were encouraged to try converting the extra-thoracic rubber œsophagus into an intra-œsophageal device. A rubber tube about No. 13 bougie gauge was therefore pulled up through the stenosis and brought out of the cervical fistula. By this means feeds could be delivered directly into the stomach through a funnel attached to its upper end. It was hoped that with this elastic dilator in situ it might be possible for the patient to drink by the mouth, the fluid finding its way into the stomach by the side of the tube. But this did not eventuate, for the œsophagus filled and the contents then leaked by the side of the tube as it lay in the cervical fistula, causing excoriation and general inconvenience. It was then decided to cut a series of holes in the intra-œsophageal part of the tube, thus providing a route to the stomach. When the rubber tube was inserted a thread was tied to its lower end, and by this means it was partially withdrawn from the gastrostomy in order that a bougie could be thrust into its open end. The tube was then withdrawn from the neck so that suitable lateral holes could be cut. Using the bougie as a pilot the rubber tube was drawn into position again, as shown in the diagram (*Fig.* 371). The cervical fistula was packed with vaseline gauze around the tube and this was held in position by a domette bandage to which the neck tube was securely fixed. The gastrostomy opening was also carefully packed, the gauze being fixed in position by strapping over a firm pad. With this apparatus in position saliva and fluids passing down the œsophagus readily found their way through the rubber tube and so into the stomach. In addition, ordinary gastrostomy feeds could be given through the tube traversing the cervical fistula. This apparatus was left in situ for six days and was quite satisfactory, the patient being able to drink fluids at almost normal rate. At the end of this time the indwelling tube was changed for one slightly larger.

Of course, the essence of the treatment was to restore the lumen of the œsophagus to such a size that normal food could be swallowed, so the apparatus was dismantled after being in use for ten days. For the next two days the patient was unable to swallow anything, but as the œdema subsided function returned and the patient found that he could not only swallow fluids, but also a little bread. Thus a further stage in treatment was initiated, for I have always insisted that each bolus of solid food swallowed is a valuable dilator. The patient eagerly pursued this method, and a few days later was able to partake of bread and meat. Of course, bougies were also used, and he managed to get up to No. 12, an instrument 7 mm. in diameter. But by this time by judicious selection he was able to take all his food by the mouth and he was discharged from the hospital on Feb. 27, exactly sixty days after admission. His progress may be summarized by stating that he entered hospital unable to swallow even saliva *per vias naturales* and left able to take a sufficiency of solid and semi-solid food by that route. The patient travelled alone to his home North of the Border and was able to report of the journey: "I swallowed a couple of bougies on the train and was able to enjoy some lunch and afternoon tea at least well enough not to excite the curiosity of my fellow passengers". What a contrast to

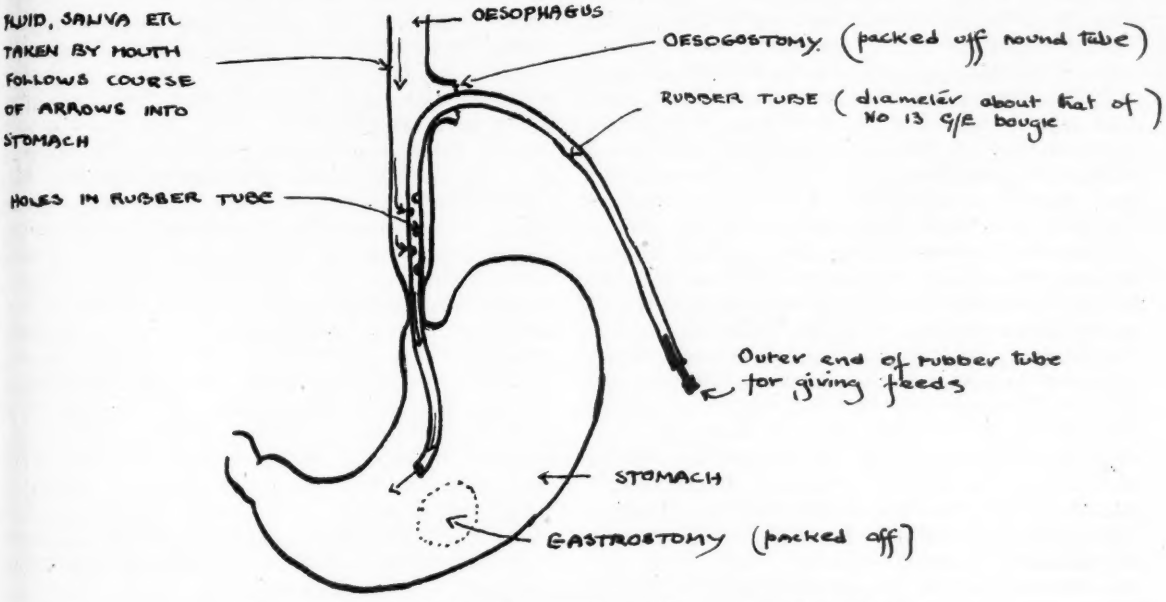

FLUID, SALIVA ETC TAKEN BY MOUTH FOLLOWS COURSE OF ARROWS INTO STOMACH
HOLES IN RUBBER TUBE
OESOPHAGUS
OESOGOSTOMY (packed off round tube)
RUBBER TUBE (diameter about that of No 13 G/E bougie
Outer end of rubber tube for giving feeds
STOMACH
GASTROSTOMY (packed off)

FIG. 371.—Diagram showing intra-œsophageal dilator and swallowing device.

the condition and the state of mind in which he made the southward journey only two months previously !

Ten days after his arrival home he reported that he had been rather over-zealous in his efforts to keep up the dilatation and that in consequence he had suffered pain and was unable to swallow for 24 hours. As the result of a period of rest and abstinence from bouginage for a few days he soon recovered lost ground and managed to pass No. 13, which was one step up since leaving hospital. By the end of March he reported that the passage of the bougies was not only free from pain but that there was not even discomfort. Thus encouraged he was tempted to step up the scale rather quickly, and to help matters he used to leave a bougie in situ between meals or even over night. About a fortnight later the patient reported that he had taken up duty as a house surgeon and that the new work and responsibilities had interfered somewhat with his treatment. Further, he found there was some pain when introducing the bougies at night, and that though he had got as high as the 19's and 20's before moving on to the next size, by leaving each gauge in situ for a number of hours, he had always to commence with a No. 10. At this stage, April, 1941, he wrote, " I am a little disappointed at the present pain and at the fact that in spite of having reached No. 20 so easily such a short time ago, swallowing is so relatively laborious and a No. 10 so firmly gripped and sometimes so difficult to introduce. Generally it takes me from 7 to 10 minutes to pass this bougie completely through at night. But swallowing is better than that commensurate with an œsophagus of a 6-mm. lumen (i.e., No. 10 bougie size), and, as I say, I am still carrying on, though I am more certain than ever that it is going to be a long job ". To this I replied, " Years ago, in connexion with the dilatation of urethral stricture I learnt that it was possible to do far too much, and now I know that it is just the same with the œsophagus. You have been trying yourself too high in your very natural desire to get quick results. Again, when you are up and about and have activities and anxieties your tissues are always much more sensitive and liable to rebel. As you say, it is going to take a long time to get well; it will be many months, perhaps even a further year or more. Your slogan must be ' hasten slowly '. Now for directions—rest whenever you can, sitting, or lying doing nothing and certainly not thinking about your œsophagus; the treatment must be without pain, so be content to pass such a size of bougie as will go down easily even if it is only No. 10. If you use such a bougie once or twice a day and perhaps leave it in for an hour or two it will do good and no harm, or pass it only once and be done with it. Passing a bigger bougie with pain or with after-pain will always do harm. Only use a bigger bougie at such times as it can be done without pain. You will find that one day some bougie will only pass with great trouble whereas perhaps on the next day or next again, after a good rest, the same bougie will pass with ease. It is too soon to have the gastrostomy closed; in fact, it would be a good thing to give yourself say the evening meal that way so as to thoroughly rest the ' swallow '. At this stage don't be disappointed to have to wash your food down. Don't think and talk about your œsophagus—occupy your mind with other things. Watch that your total of nourishment is sufficient—if they suit you, make up with eggs and milk ". In a few days the patient hastened to write: " Almost all of what you say I have already worked out for myself. I have had a complete rest and find swallowing to be greatly improved. I know now how true it is that I must ' make haste slowly ' and shall certainly adopt that as my text. I do not mind at all having to wait a year or two for full dilatation and the closure of my œsophageal fistula. My gastrostomy is, however, a very different proposition. It is responsible for most of my present discomfort, which is not much I hasten to add, but it has an immense ' nuisance value '. It leaks at night occasionally and as I mentioned in my last letter aches considerably if I get overtired, acting in this latter respect very much as a ventral hernia. So just as soon as you consider it feasible I should like it done, for I know how very much happier I will be without it. However, after having had it for the last twenty years I'll easily manage to stick it for another month or two. In conclusion, I am very happy and full of hope for the future, whatever future is left in these crazy days. I am fully confident of ultimate success."

During this time he was doing all the duties attached to his resident post and was able to enjoy the opportunities it afforded. With one exception his chiefs were quite unaware of his disability. About the middle of May he was able to report: " My own progress is magnificent. Following upon your advice to use bougies only daily, I have made immense strides. Swallowing is so good now as never to cause me the slightest apprehension. I now start daily at No. 12 and using one after the other proceed to No. 15. I will presently try beginning at No. 13, but I still stick to '*festina lente*' as a guiding motto. I spend half an hour daily using bougies and take regular rests, having two or three days off after about five daily dilatations. The treatment is entirely without pain or discomfort either before or after. I have actually gone eight days without using bougies and without noting much depreciation in my swallowing capacity, and have then resumed on the ninth day with No. 11 and have gone straight up to 15. That was during the recent heavy ' blitzes '. I had taken my usual three days rest when they started and kept it up for three successive nights. I was so tired and was working so hard that I simply dispensed with bougie treatment until I had had a couple of restful nights. And in spite of it all swallowing

continued well, and as I have said I lost no ground at all. I eat everything and anything and can assure you that I have never swallowed better in my life. It seems almost incredibly rapid progress after only about five months' treatment. I regularly enjoy meals in restaurants and quite revel in my new-found pleasure of natural swallowing. I had an exacerbation of gastric disturbance after the above-mentioned blitzing, with all its extra fatigue, but it has responded well to simple treatment and once again I must say I feel magnificently well."

The patient continued to make excellent progress and in July wrote: "My progress has been easily maintained. I have been using bougies much less often and have remained for some time at No. 15, that is, I can be pretty sure of starting at that figure and rising on successful days to No. 17. I have purposely gone for fifteen days without using a bougie with a view to knowing how long I could let pass after operation before resuming dilatation. And during that time I did not lose much, if any, swallowing ability." He was now eager to have the gastrostomy closed and was readmitted for that purpose on Aug. 4, 1941. The following epitome was written at this time. "The patient was discharged at the end of February, 1941. At that time he was taking most of his feeds by gastrostomy and could only take a few by mouth. He was able to swallow a No. 10 bougie. After discharge he was able to take more and more by mouth, and on March 17 dispensed altogether with gastrostomy feeding. He can now take everything by mouth and is never troubled by indigestion except after being fatigued. He can always pass a No. 15 bougie, and sometimes can manage a No. 17. He is readmitted for *closure of the gastrostomy*."

The operation was carried out under general anæsthesia. An elliptical incision was made round the gastrostomy and the dissection was carried down to the peritoneum, which was freely opened. The stomach was thoroughly separated from its attachment to the parietes. The margins of the separated mucous membrane readily tore, and were excised, leaving only the strong healthy stomach wall for suturing. After separation from the parietes there was an aperture in the stomach about 3 in. across. This was closed in the vertical direction to avoid all risk of narrowing the lumen of the viscus. Suture was of chromicized catgut in two layers and was made without difficulty. As far as possible the abdominal wall was closed by layer suture with the addition of three through-and-through stitches of stout silkworm. Recovery was straightforward, the wound healing kindly. The patient took ordinary food by the mouth, was soon out of bed, and left hospital at the end of a fortnight.

Early in October the doctor wrote me: "I am enjoying excellent health and a new-found physical freedom. Bouginage has not progressed. I can swallow Nos. 15 and 16 at any time and with no trouble, but No. 17 is still very tight. Occasionally I manage to get it through with patience, but it nearly always leaves me with a tender spot in the œsophageal mucosa which prevents further use of bougies for a day or two. All of which worries me not at all, because swallowing of No. 16 standard is quite excellent, and though I want to carry on until I reach higher diameters, I am perfectly satisfied that I can swallow any normal meal with no difficulty; and in fact never give the subject very much thought so satisfactory is the present 9-mm. diameter œsophagus. I am very much happier than ever before and well rid of my long-standing gastrostomy." On Nov. 14 the patient very kindly made the journey to London so that he might be presented as an interesting case to a meeting of the Moynihan Club held at Hammersmith Hospital. On that occasion he spent the morning in the wards with the visitors. During an interval he was demonstrated to my friends, who saw the open cervical fistula, the scarred chest wall and the area of the closed gastrostomy. He then packed the cervical fistula with gauze and a little later sat down with the party and enjoyed an ordinary lunch consisting of soup, chicken with vegetables, sweet, cheese biscuits, and coffee. This meal he ate with avidity and as if nothing had ever been the matter with his swallowing apparatus. The patient continued in good health, and by March, 1942, was able to report: "Have been working very hard, I remain at No. 16 in bougies, have several times tried No. 17, but though it engages firmly in the stricture, it rarely goes fully through and is nearly always rather painful." None the less he was taking food with ease and was looking eagerly forward to the closure of the œsophagostomy.

For this purpose he was readmitted to Hammersmith Hospital on March 22, just about fifteen months after treatment of the œsophageal condition was undertaken. The following note was made: Since discharge in August, 1941, following closure of gastrostomy, the patient has kept fairly well. Has had two or three attacks of "gastritis", lasting 2 to 3 days each, and marked by anorexia, nausea, and half-hour bouts of gnawing epigastric pain relieved by antacids. No actual vomiting or pyrosis, though a little associated flatulence. Bowels regular and motions normal. He finds the fatigue induced by several successive long days of operating in the theatre predisposes him to "gastritis". Otherwise he has been busy as an R.M.O. since five days after his last discharge from this hospital and until the beginning of this month. Has been passing No. 16 bougie since leaving. Passed it once every week or two till four months ago, since which time he has hardly found time on account of his work to use the bougie more than once every three or four weeks. Since going on holiday he has used bougies five or six times. Lately he has managed to pass No. 18 three times,

the bougie taking some five minutes to traverse the stricture each time. At each passage of bougie, he leaves it down from half an hour to two hours and always introduces it through the

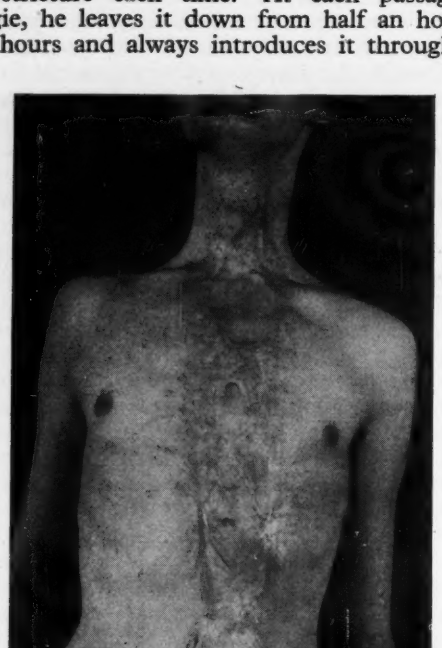


FIG. 372.—Scarred condition of skin of chest wall after closure of œsophagotomy and gastrostomy.

œsophageal fistula. On examination he was a well-nourished young man of good colour, with large oval œsophageal fistula to left of jugular notch, and having the outer border of the sternal slip of left sternomastoid as its lateral boundary. The œsophageal lumen presents several polypoid tags on its posterior and left lateral walls, and a more or less horizontal shelf across its posterior wall. Scar of closed gastrostomy in left epigastrium. The following operation for *closure of cervical œsophagostomy* was carried out: Under intratracheal anæsthesia the small polypi were snipped off with scissors and were subsequently shown to be adenomatous in structure. An incision was made through the skin encircling the orifice and separating the surface skin from that lining the œsophagostomy. The fistula was then very carefully dissected free from its supporting firm fibrous tunnel and from its attachment to the deep surface of the sternomastoid. The freed edges were then sutured together by introducing the stitches from within, beginning from either end and meeting midway. Secondary sutures were used to draw the cellular tissues together over the first suture line. The skin margins were then drawn together with mattress sutures in order to bring broad surfaces into apposition. Interrupted stitches completed the skin suture. The lower angle of the skin incision was left unsutured to accommodate a rubber drain. Bipp was smeared over the restored œsophageal tube and also over the skin surface around the sutured wound. Returned to ward with rectal drip. Nothing allowed by mouth for first 48 hours. In this operation no attempt was made deliberately to expose the œsophageal wall, though the muscular fibres were seen on the anterior margin. The opening was actually closed by turning over skin-flaps like a lid, as in this way there seemed to be no risk of causing narrowing. As a result, after concluding the suturing the newly constituted wall at this point appeared a little redundant, but in the after-progress there has been no sign of bulging or weakness. Recovery was uneventful. (*Fig.* 372.)

The drain was removed from the wound on the fifth day, after which its track very rapidly healed. By this time the patient was taking porridge and other semi-solid foods. By the eleventh day the wound was completely healed and he was enjoying ordinary food. By the middle of May the patient reported that he was quite well and taking food with ease. Thereafter he soon began work, assisting in a practice, and this he was able to do without experiencing disability of any sort. At the time of writing, some twelve months after this operation, the result remains entirely satisfactory.

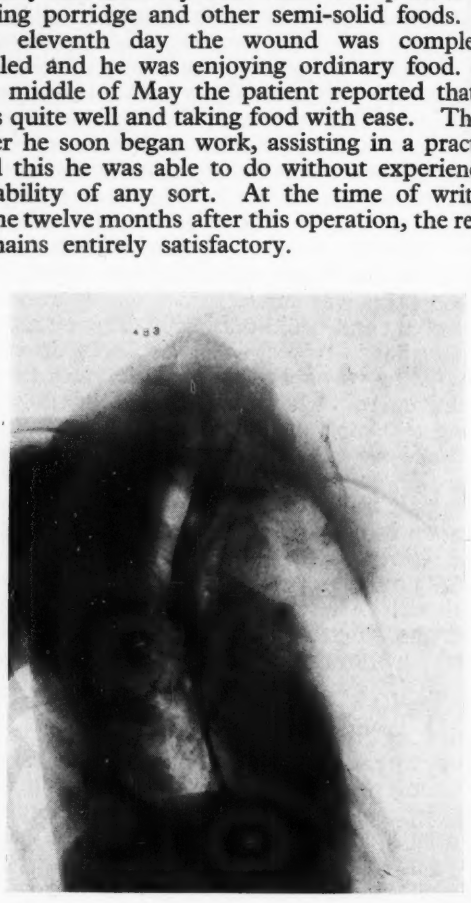


FIG. 373.—Radiograph showing degree of restoration of œsophagus two years after commencement of treatment by bougies. Patient able to swallow ordinary food like an ordinary person.

As to immediate after-history, in June he had a severe attack of chicken-pox, but soon recovered, and in July took up his duties as one of my house surgeons at Hammersmith Hospital. In this capacity he worked hard and never spared himself in any way, taking his turn with the others in all the multivarious duties of the post, including the usual share of night work. During

this time he had a good appetite and took his food without the slightest hesitation or inconvenience. The general condition steadily improved, and towards the end of his service he was fitter and weighed more than at any time since hospital treatment ended. On Dec. 18, 1942, he used a bougie for the first time in six months. It was a No. 16, which went down with ease. An opaque drink showed that there was no hold up and that the act of swallowing was as observed in a normal person (*Fig.* 373).

COMMENTS

This case shows how careful we must be in concluding that complete obliteration of the œsophagus exists. In all tubes, unless there is complete severance with retraction of the ends, obliteration by scar tissue resulting from inflammation and fibrosis seldom occurs, and it is remarkable how often a tiny channel with a mucous lining persists. In the days when urethral stricture was very much more common than it is to-day we talked rather glibly about obliteration of the urethra, but that was really a most unusual event. It is important to recognize this pathological point, because it appears to be established—as the old-time surgeons well knew—that if a passage exists, however minute and meandering, it can be successfully dilated. In the thoracic œsophagus this is particularly important, because this part of the tube is not safely amenable to direct surgical attack, and it is not easy to apply the principle of short-circuiting. In this particular case there can be no question of canalization, for the bougies discovered the channel, and in any event they were so fine and pliable that it is quite impossible that they could break a way through a mass of scar tissue. Those who are really interested in the management of these difficult cases will, I hope, welcome the details of the bougie treatment. All must be struck by the way that general health and fitness influence the problem. I am not undertaking a discussion of the alternative methods of treatment which might have been employed because I want by this record again to emphasize the importance of the intelligent use of bougies. A large part of the credit for the successful result belongs to the patient, whose ingenuity and perseverance so ably seconded his enthusiastic collaboration.

Once again may I thank my associates at Hammersmith for their help, and Dr. Daley, principal Medical Officer of the L.C.C., for permission to publish this record.

REFERENCE

[1] TURNER, G. GREY, *Brit. Jour. Surg.*, 1939, **26**, 555.

In Memoriam

GEORGE WASHINGTON CRILE

1864–1943

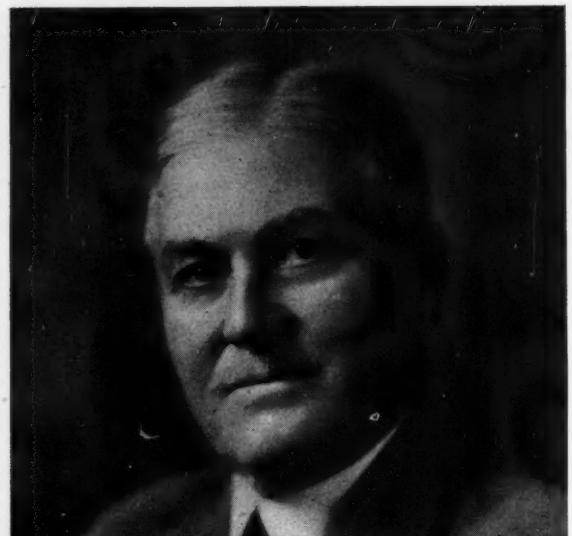
THE death of George Crile has removed from the medical profession one of the most colourful and stimulating characters of this time and generation. He was a typical American product, highly endowed with those characteristics of vivacity, inquisitiveness, and desire to see and do everything in his lifetime that are common characteristics of the American people. He was born in the small town of Chili, Coshocton County, Ohio, on November 11, 1864. When 16 years of age he went to Ohio Northern University, at Ada, Ohio, graduating in 1884 with a degree A.B. He then entered the Worcester Medical College in Cleveland, where he received his medical degree (M.D.) in 1887. There then followed an internship at the Lakeside Hospital, Cleveland, Ohio. After a period of travel he settled in practice in Cleveland, Ohio, and in 1889 became Demonstrator in Histology at the Worcester Medical College, which later became a part of the Medical School, Western Reserve University, in which he later became Professor of Surgery. It is perhaps characteristic of George Crile that his inquisitive, ebullient nature made him a physiologist rather than an anatomist from the beginning. Although he began in the Department of Histology, he was at the same time conducting physiological investigation, and it is no surprise to those who knew him later that by 1890 he became a teacher in the Department of Surgery. Again characteristic of this vigorous personality is the fact that for for some fifteen years he taught anatomy, physiology, and surgery, and was accepted by the students as an authority in each.

Surgery eventually claimed the extraordinary talents of George Crile, because he was most suited to that walk of life. Although he boasted a never-ending curiosity, that curiosity was not satisfied by experimental endeavourment on animals, but had to be elaborated by a final trial of the knowledge he had acquired on the human body. Indeed, the ills of the body, as he saw them in patients, became the recurrent stimulus to his physiological endeavours, and problems which he saw in patients were taken back to the laboratory for enlightenment.

Again characteristic of the man was the fact that with the outbreak of the Spanish-American

War he wished for experience in service, became a First Lieutenant in the Medical Corps, and saw service in Porto Rico.

His progress in surgery was rapid, for he not only was a good surgeon, with an excellent education and training, but he had that geniality of character which endeared him to people, and thus his private practice grew by leaps and bounds.



GEORGE WASHINGTON CRILE

1864—1943

In his late thirties, he became Professor of Surgery at Western Reserve University, and Chief Surgeon at the Lakeside Hospital, a post he held until retired by the age limit in 1924. This period was perhaps the one of his greatest activities, for during this time he became greatly interested in the surgery of the thyroid gland, and his initial work on anoci-association and its relation to surgery was brought up. This latter interest was brought forward because of his belief that people, even under anæsthesia, suffered injury to their nervous system, and he thus acted as a stimulus towards more gentle surgery, both in his own country and abroad, pointing out the bad effects of trauma at the hands of the surgeon, always attempting to gauge the anæsthesia to the necessary degree and using as little anæsthesia as possible. It was his ideas along these lines that greatly increased the use of local anæsthesia, for he attempted to block the nervous pathways from the surgical field by the liberal use of novocain anæsthesia. Even then patients would like to be anæsthetized with a general anæsthetic. In his search for a general anæsthetic which did not harm the patient, he became the ardent supporter of nitrous-oxide and oxygen anæsthesia, which unless accompanied by the use of local anæsthesia was unsuited to major surgical endeavours.

Moreover, during this period the First Great World War arose, and his unit (Base Hospital No. 4), organized at the Western Reserve University in Cleveland, Ohio, was the first medical unit to reach Great Britain, and was assigned to the British forces in Northern France. In his curiosity to understand shock, the effects of trauma was given full vent, and he carried out experiments on animals even during the period of the war and in the forward areas. Before he came to the theatre of war his interest in blood transfusion had been a major factor, and his stimulating character and his interest in shock made him a leader in the use of transfusions in the British and American Armies in the last war.

After the war he came back to set up a private clinic modelled on that previously established by the Mayo brothers, and this great clinic carries on to-day the traditions established by its founder.

It was natural that a man as vigorous and as curious and as personally attractive as this American should achieve honours in many directions. He was a member of every great surgical society in his own country. He had been President of the Society of Clinical Surgery, and the American Surgical Association, the leading surgical associations in America. He was a retired Brigadier-General of the United States Army Medical Reserve Corps. He was a member of the Royal College of Surgeons of England, being made an Honorary Fellow on July 31, 1913.

There is no space here to enter in detail the many publications and the full works of this colleague. He stands out in his day as a great leader, a pathfinder in surgery, for though he may not have always turned down the right path, his stimulating character led people to follow and prove or disprove his constantly arising theories and questions. He is almost the last of a unique group of surgeons in America, notably, the Mayos of Minnesota, Murphy of Chicago, Ochsner of Chicago, Cushing of Boston, Brewer of New York, and Finney of Baltimore, who founded the Clinical Surgical Society, and who, in each others' company, went forward to great careers, to the benefit of mankind. This JOURNAL is proud to honour him by this notice of his loss to a universal group of colleagues.

EXPERIMENTAL SURGERY

THE EFFECTS OF STRETCHING NERVES AFTER SUTURE*

By W. B. HIGHET AND F. K. SANDERS

FROM THE NUFFIELD DEPARTMENT OF ORTHOPÆDIC SURGERY (PERIPHERAL NERVE INJURY CENTRE) AND THE DEPARTMENT OF ZOOLOGY AND COMPARATIVE ANATOMY, OXFORD

In the surgical treatment of extensive lesions of the peripheral nerves the standard procedure is to resect the damaged segment of nerve until satisfactory proximal and distal cross-sections are obtained. In order to perform nerve suture the gap left after resection is closed by a combination of manipulative procedures (Stiles and Forrester-Brown, 1922), of which the most important is the shortening of the course of the nerve by flexion of one or more of the joints over which is passes. Following nerve suture the nerve is elongated by gradual extension of the flexed joints.

The ease with which end-to-end suture can be achieved across quite large gaps by this method has led many authors (Naffziger, 1921; Platt, 1921; Platt and Bristow, 1924; Babcock, 1927) to recommend its use to the exclusion of any bridging procedure. However, while it is well known that intact peripheral nerves exhibit considerable tolerance to stretching (Weir Mitchell, 1872; Baron and Scheiber, 1917), very little is known of what takes place during the post-operative elongation of resected and sutured nerves.

There is no doubt that functional recovery frequently occurs in nerves which have been sutured and then stretched post-operatively (Forrester-Brown, 1921), but the results of end-to-end suture in war cases fall very far short of the results of nerve repair in civil injuries, and it is not known whether the discrepancy is due partly to the effects of post-operative stretching, besides the complications introduced by scarring and delay of operation. Stookey (1922) reports two cases of bulb suture where cross-sections of the bulbs resected after a course of post-operative stretching showed loss of normal pattern in the proximal stump, with a great increase in peri- and endoneurial scar tissue far above the level of the lesion, and Highet and Holmes (1942) give four further cases in which similar changes took place.

No controlled study of post-operative nerve stretching appears to have been made experimentally. It is not known to what degree a nerve may be elongated without rupture of (*a*) blood-vessels, or (*b*) nerve-fibres, or if gradual elongation is likely to be less damaging than when the extending force is rapidly applied. Moreover, it is unknown whether a nerve elongated by this procedure remains permanently under tension, or actually 'grows' and regains its normal laxity. Baron and Scheiber (1917) noted by means of X rays the behaviour of silver clips placed above and below the suture line during post-operative nerve stretching in man. They found that the clips moved distally along the limb as well as moving apart slightly, indicating that elongation was taking place along the whole length of nerve, but did not determine whether this elongation was permanent or whether it was distributed uniformly along the whole length of the nerve concerned.

Takimoto (1916–7) made a histological investigation of the results of rapid elongation of intact nerves in rabbits, and found that sudden, severe, stretching of the sciatic nerve caused segmental break-up of axons and myelin, bleeding, hyperæmia, tearing of connective-tissue bundles, and widening of the lymph-spaces in the epi- and perineurium. Wallerian degeneration followed in the interrupted fibres. However, there is evidence that a more gradual stretching is less damaging. In leg-lengthening and operations for the correction of contractures in rheumatoid arthritis, the nerves in the calf may be lengthened by as much as 6 cm. in 3 weeks without the appearance of sensory or motor disturbances (Seddon—personal communication).

The experiments described in this paper were therefore undertaken in order to discover: (*a*) whether post-operative stretching of sutured nerves causes such damage as is likely to interfere with regeneration, and, if so, whether the damage following rapid stretching is likely to be more extensive than that following a gradual elongation spread over a number of days; (*b*) whereabouts in the nerve the elongation takes place; (*c*) whether post-operative stretching involves 'growth' in the length of nerve so elongated, or whether the nerve returns to its original length whenever the joint is flexed subsequent to the original extension by which elongation of the nerve was accomplished.

With the hind limb in extension, extensive resections were made of the external popliteal nerve in the thigh in a number of dogs, the nerve gap closed by flexion of the knee, and suture

* The experiments described in this paper were made as a corollary to the clinical investigation reported in the January number of the JOURNAL by Highet and Holmes (1943). The two papers should thus be read in conjunction.

performed. The animals were kept for a fortnight in a plaster cast with the knee flexed, and the limb then extended, either gradually or rapidly. The extent and magnitude of the elongation was determined by taking X-ray photographs, both before and after this extension, of a number of silver clips placed along the course of the nerve at operation. Finally, the animals were sacrificed at a standard time after operation, and the histological condition of the stretched nerves examined.

METHODS

Operative Technique.—The animals used were adult dogs of both sexes. In an initial aseptic operation under anæsthesia (ethyl chloride induction followed by open ether) the sciatic nerve was exposed in the thigh and the internal and external popliteal divisions separated from each other. The external popliteal nerve was then mobilized from the sciatic notch to the point at which it enters the fascia at the level of the fibula. To facilitate this mobilization the bicipital artery and vein were ligated, biceps femoris tendon severed at the knee, and the muscle turned back. The internal popliteal nerve was also mobilized from the sciatic notch to its entry into the gastrocnemius.

In order to determine the maximum length of nerve which could be resected and still allow end-to-end apposition of the stumps when the knee was fully flexed, the following measurements were made on the external popliteal nerve: with the knee in full extension two stay sutures about 100 mm. apart were inserted through the nerve. Gentle traction was then exerted upon the sutures so as to bring them closer together, and the distance between them was measured. The knee was then fully flexed, the sutures brought closer together by gentle traction on the nerve, as in the first measurement, and the distance between them measured a second time. This gave the following measurements: (1) Distance between stay sutures with limb extended and tension applied; (2) Distance between stay sutures with limb flexed and tension applied. The difference between these two measurements gave the maximum resection which could be made while still achieving approximation of the stumps with knee in flexion. In practice a few millimetres less than this length of nerve was excised since the nerve is more extensible when the limb is in flexion.

The limb was then fully flexed at the knee and the stumps of the cut external popliteal nerve sutured together. This was done in one of two ways: (*a*) in the earlier experiments two epineurial sutures of black silk were used, but it was found histologically that these occasionally set up a considerable tissue reaction (*see also* Guttmann, 1943); or (*b*) in the later experiments the nerve was sutured by means of a single through-and-through stitch of white silk. Little difficulty was experienced in getting the stumps together under these conditions, and after suture the nerve lay approximately along a straight line connecting the sciatic notch to the point of entry of the nerve into the fascia covering the shank muscles, under little or no tension. Out of 7 animals, the suture was in 6 cases made in the lower third of the thigh, and 1 case in the upper third.

Several silver clips were then fixed at known intervals along the course of the nerve from the sciatic notch to the lower limit of mobilization, the clips being inserted through the epineurium only, and clamped tight by means of a pair of artery forceps. The top clip was always placed at the level of the sciatic notch, and the bottom clip a short distance above the entry of the nerve into the fascia overlying the shank muscles. One clip was always placed on each side close to the suture line.

The wound was then closed in layers, the biceps tendon being resutured and the limb fixed in a position of extreme flexion at the knee by means of a plaster cast.* Great care was taken to avoid any extension of the knee in the period between the actual suturing of the nerve and the application of the plaster.

X-ray Photographs.—Fourteen days later the plaster cast was removed and an X-ray photograph taken of the clips with the limb still kept in flexion. Then either (*a*) without extending the limb, a further plaster was applied—this plaster was hinged at the knee and bore a light screw turnbuckle by means of which the knee-joint could be extended; or (*b*) the animal was allowed to run free. In the animals with a turnbuckle plaster gradual extension of the knee was brought about by screwing out the turnbuckle an equal number of turns a day, in such a way that extension was complete in 14 days. In the animals allowed to run free rapid extension was brought about through the animals' own movements. In the animals with turnbuckle plasters, when extension was complete (14 days after the plaster change) the plasters were removed and two X-ray photographs taken of the clips, one with the limb in flexion, and one in extension. Comparable photographs were made 14 days after plaster removal in the animals which had been allowed to run free. All the animals were then allowed to run free for a further 7 days, when another pair of X-ray photographs of the clips were taken. The animals were then sacrificed, 35 days after resection and suture of the nerve. Out of 7 dogs which were brought successfully through all the stages of the experiment, 3 had their knees extended by means of a turnbuckle, and 4 were allowed to run free after the first plaster removal. By comparing the distances

* Great difficulty was at first experienced in preventing the dogs from removing their plasters. Finally, this was achieved by applying to each dog, in addition to the plaster spica, a light plaster collar attached to the plaster spica by webbing straps, one on each side of the body.

between the various clips in the X-ray photographs it was possible to determine the amount of elongation of the nerve and where it had taken place. The distances between the clips as estimated from the X-ray photographs were checked by measurements made directly upon the exposed nerve (*a*) in *flexion* at operation, and (*b*) in *flexion and extension* at autopsy before mobilizing the nerve. It was found that the use of the X-ray photographs for measurements did not introduce any appreciable error into the absolute value of the inter-clip distances recorded.

Histological Methods.—At autopsy pieces of the nerve were removed for sectioning and staining by various methods. The routine methods were: for axons, the Bodian silver proteinate; for myelin, fixation in Flemming's fluid, followed by staining with a modified Weigert-Pal stain; and for other structures, hæmatoxylin and eosin, and the Masson and Azan-Mallory trichrome methods. Pieces of nerve were taken at all levels from the entry of the nerve into the shank muscles, right through the sciatic plexus, to the various roots and trunks of the plexus which supply the external popliteal nerve. Specimens of the dorsal and ventral roots, and the regions of the spinal cord supplying fibres to this nerve were also taken.

Controls.—In every animal a control was provided by the internal popliteal nerve. This was subjected to the same mobilization procedure as the external popliteal, and cut and sutured without resection at the same operation.*

A control of the clip procedure was given by two normal animals, in which the nerves were exposed at an initial operation, mobilized, and, without resection or suture, clips were placed along the course of the external popliteal nerve exactly as in the experimental animals. X-ray photographs were taken of the position of the clips during flexion and extension of the knee, in order to discover what movements of the normal nerve take place during limb movement. Thirty-five days after operation both these animals were killed, and when examined histologically showed that the insertion of the clips caused no gross degeneration of fibres within the nerve.

RESULTS

Behaviour of the Normal External Popliteal Nerve during Movement of the Knee.—In a moderate-sized dog the external popliteal nerve enters the muscles it supplies 20–30 mm. distal to the knee-joint. At the point of muscle entry the nerve is fixed by the fascia and is less mobile than elsewhere. Thus extension of the knee carries the muscle insertions downward and causes an increase in the length of the course of the nerve between the points of muscle entry and the origin of the nerve in the sciatic plexus. Study of the X-ray photographs of dogs with mobilized but otherwise intact nerves showed that this increased distance is made up along the course of the nerve in two ways: (*a*) When the limb is flexed at the knee the course of the nerve between the hip-joint and the points of muscle entry is not a straight one, the nerve curving into an S-shape in the popliteal space. Hence the first effect of knee extension is to straighten out these tortuosities, so that when the knee is partially extended, and before the nerve can be subjected to any tension, the nerve comes to lie along a straight line connecting the hip-joint to the muscle entries. (*b*) Further extension of the knee causes the nerve actually to stretch. Since the dog does not maintain an erect posture, the sciatic nerve normally bends sharply around the hip-joint. Thus, stretching of the nerve, besides causing the segment of nerve lying in the thigh to extend, causes elongation of the nerve above the hip-joint, the effect being to pull more nerve down into the thigh around the pulley provided by the hip-joint. Extension of the knee thus causes the external popliteal nerve (*a*) to straighten, and (*b*) to stretch. *Fig.* 374 presents diagrams showing the course of these movements.

By means of measurements made upon the X-ray photographs it was possible to determine the relative importance of the straightening and stretching components in making up the increase in the length of the course of the nerve which takes place during knee extension. It was found that by far the most important component is the straightening out of the nerve, stretching of the nerve playing only a minor part. For example, in Dog 27, in which movement of the knee-joint from the position of full flexion to full extension caused the course of the nerve to be lengthened by 51 mm., straightening of the course of the nerve allowed for 38 mm. of this increase. The remaining 13 mm. was made up by stretching of the nerve. The nerve in the thigh elongated by 7 mm., while, as a result of elongation of the nerve proximal to the hip-joint 6 mm. of nerve was pulled down into the thigh.

Behaviour of the External Popliteal Nerve during Movement of the Knee after Resection and Suture.—Post-operative stretching of a resected and sutured nerve, when brought about by joint extension, results in the same total increase in the length of the course of the nerve as normally accompanied movement of that particular joint. However, when part of a nerve is resected, and the stumps brought together by subsequent flexion of the limb, apposition will be achieved at the expense of tortuosities which would have appeared in the course of the nerve had it not been resected, and possibly, by the application of tension to the stumps. Thus, the course of a resected and sutured nerve in the flexed limb at the beginning of post-operative nerve stretching will be straighter than normally. So, during post-operative nerve stretching,

* In the first few experiments an attempt was made to use the external popliteal nerve of the opposite side of each animal as a control. However, the animals tolerated the double operation very badly.

stretching of the nerve can be expected to account for more of the increase in the length of the course of the nerve than the straightening out of tortuosities. That this is indeed the case is shown by the magnitude of these components worked out in the case of 7 animals and given in *Table I*. In these differences between the behaviour of the nerve during normal limb extension and during post-operative stretching are summarized in *Fig.* 374. The changes of position of the clips in the X-ray photographs of a single case are shown in *Fig.* 375.

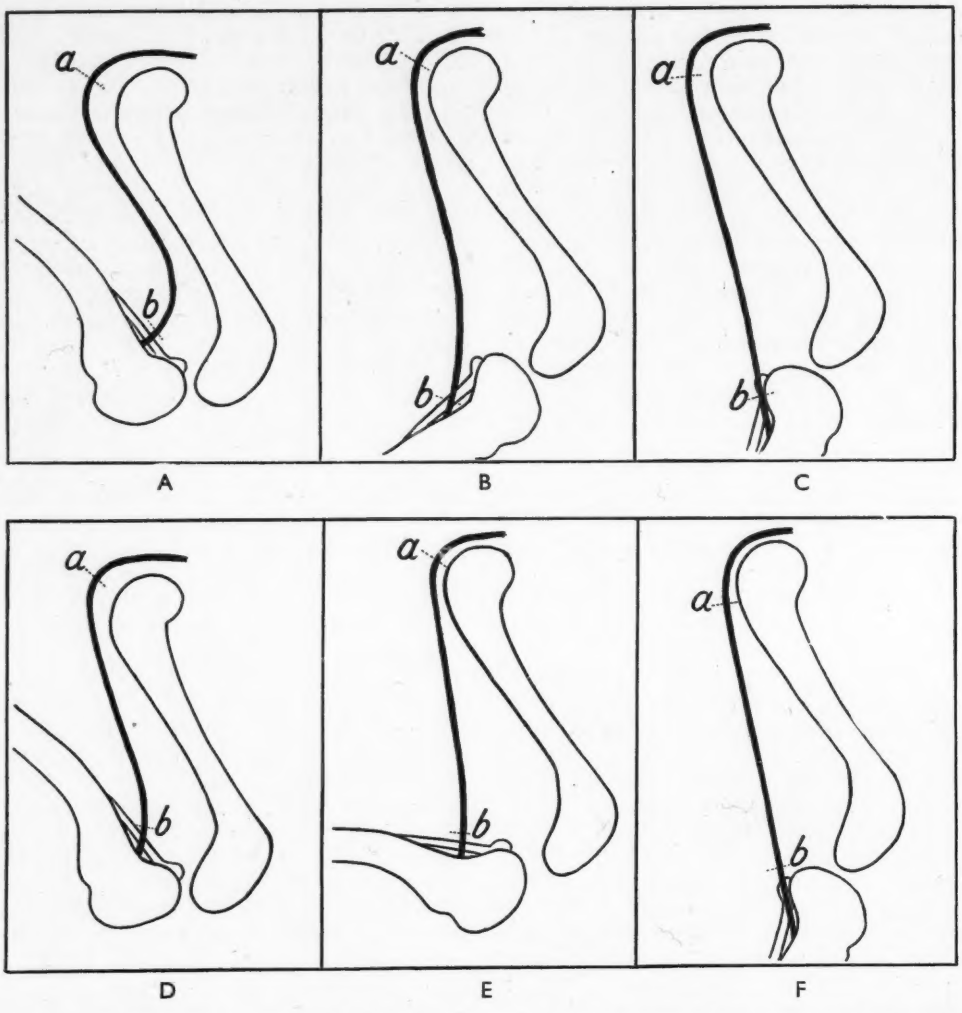


FIG. 374.—A–C, Diagrams to show the behaviour of the external popliteal nerve during extension of the knee in a limb containing a mobilized but otherwise intact nerve. A, Shows the S-shaped course of the nerve in extreme flexion. B, Considerable extension of the knee has straightened out this tortuosity without stretching the nerve. C, Shows the slight stretching of the nerve occurring on the completion of extension.

D–F, Diagrams to show the behaviour of the external popliteal nerve during extension of the knee in a limb containing a resected and sutured nerve. D, Shows the position of the nerve in extreme flexion. The course of the nerve is less tortuous than in A. E, Shows that much less extension of the knee is required before the nerve begins to stretch than in B. F, Shows the considerable elongation that takes place when extension is completed, particularly in the distal part of the nerve. a, Topmost clip; b, Lowermost clip. For further details, *see* text.

animals the nerve elongated by between 33 mm. and 57 mm., compared with the 13 mm. seen in normal nerves. Conversely the gain due to straightening of the nerve varied between 2 mm. and 14 mm., compared with 38 mm. in normal nerve. Post-operative nerve stretching thus results in greater elongation of the nerve than normally takes place during movement of the limb, and therefore the application of greater tension to the nerve than normally occurs. These

Distribution of Elongation along the Course of the Nerve.—It has been shown that during post-operative stretching the nerve elongates throughout its length, and undergoes a proportionately greater elongation during extension of the limb than occurs in a normal, unresected nerve. By means of measurements made upon the X-ray photographs it was possible to discover how the total elongation of the nerve produced by stretching was distributed along the course of the nerve.

Since silver clips were only placed along the nerve in the thigh, this part of the nerve was considered by itself.

In normal nerves the total elongation in the thigh was found to be distributed uniformly along the length of the nerve. In nerves stretched after resection and suture the distribution of elongation, and therefore of tensions, is not uniform. The percentage elongation occurring in different parts of 7 resected and sutured nerves is shown in *Table II*, in the compilation of which the nerve was considered in four segments. Since a clip was always placed close to and on either side of the suture line, these four segments were: (*a*) in the central stump from the topmost clip to the clip immediately above the suture line; (*b*) in the short length of nerve between the clips placed on either side of the suture line; (*c*) in the peripheral stump from the clip directly below the suture line to the lowermost clip; (*d*) in the peripheral stump between the lowermost clip and the posterior border of the tibia, which, for the purposes of calculation, was taken to represent roughly the level of muscle entry. In these four segments the percentage elongation was calculated as follows: the distance between the clips delimiting each segment was first measured upon the X-ray photograph taken with the knee in flexion before post-operative stretching was begun. A second measurement was made of the length of these segments in the photograph taken with the limb in extension after the nerve had been stretched. The increase in the length of each segment, expressed as a percentage of the measurement made in flexion, gave the percentage elongation for each segment. Similarly, the total percentage elongation of the nerve in the thigh was calculated. Were the elongation uniform, each segment of nerve would show the same percentage elongation, and this value would also equal the total percentage elongation of the nerve in the thigh.

A

B

C

FIG. 375.—Radiographs of Dog 19: A, In flexion before post-operative nerve stretching was begun; B, In extension after stretching had been completed; C, In flexion after nerve stretching had been completed.

Table I.—GAINS IN LENGTH BY STRAIGHTENING THE COURSE AND STRETCHING THE NERVE IN NORMAL AND RESECTED AND SUTURED NERVES (*see* text)

	ANIMAL	GAIN BY STRAIGHTENING	GAIN BY STRETCHING
		mm.	mm.
Normal Nerves	21	36	11
	27	38	13
Resected Nerves	26	10	33
	20	5	40
	18	2	44
	23	4	47
	19	8	47
	16	14	49
	24	6	57

Table II.—PERCENTAGE INCREASE IN LENGTH OF VARIOUS SEGMENTS OF POST-OPERATIVELY STRETCHED EXTERNAL POPLITEAL NERVES IN THE THIGH

ANIMAL	TOTAL ELONGATION	ELONGATION IN CENTRAL STUMP	ELONGATION AT SUTURE LINE	ELONGATION IN PERIPHERAL STUMP	ELONGATION BELOW LOWEST CLIP
26	25	6	19	11	100
19	25	11	0	0	227
18	33	29	45	16	80
24	35	12	0	0	74
16	36	16	0	86	147
23	38	6	17	4	387
20	42	0	44	42	41

Table II shows that except for one animal (Dog 20), which differed from the others in that the suture was made high in the thigh, by far the greatest elongation took place in the peripheral stump distal to the lowermost clip. The clip and the posterior border of the tibia (*see Fig.* 374 C, D) moved apart by an amount equal to between 74 per cent and 387 per cent of their original distance apart, while the percentage elongation of the whole nerve varied only between 25 per cent and 42 per cent. It is improbable that the excessive elongation (as expressed by distances between the clip and the posterior border of the tibia) which takes place in this region is entirely due to stretching of the nerve, since it is shown below (*see* p. 361) that in subsequent flexions of the limb, the lowermost clip and tibia return to their original distance apart. To stretch by 387 per cent and then return to its original length the nerve would have to possess an elasticity as great as that of rubber! In all probability when the segment of nerve distal to the lowest clip reaches the limit of its extensibility, stretching of the fascia and pulling out of the muscle bellies in the direction of the sciatic notch occurs, and as clips were placed along the nerve only, the movement is not shown on the radiograph. Thus, while actual amounts of *elongation of the nerve* distal to the lowest clip are certainly less than the percentages given in *Table II*, the nerve in this region is without a doubt pulled out to the limit of its extensibility, and is thus subjected to greater stresses than other parts of the same nerve (*see Table II*). Comparison of *Fig.* 375, B and C shows this disproportionate elongation of the more distal parts of the nerve.

More proximally the peripheral stump does not undergo so extensive an elongation as in the distal region, the values recorded being very variable. In one animal (Dog 16) in which the 'elongation' at the most distal level was 147 per cent, the nerve increased in length by 86 per cent immediately below the suture line. In 4 further animals (Dogs 19, 23, 26, 18), in which the elongation immediately distal to the suture line was measured, the nerve increased in length in this region by 0, 4, 11, and 16 per cent, while further distally the percentage elongation was 227, 387, 100, and 80.

The amount of elongation taking place in the central stump was always less than the percentage elongation applied to the nerve as a whole. It varied between 6 and 29 per cent.

In the short segment containing the suture line, elongation did not take place at all in three animals (Dogs 16, 19, and 24). In two animals (Dogs 23 and 26) elongation of a value less than the percentage elongation applied to the whole nerve took place, and in two further animals (Dogs 18 and 20) percentages of elongation slightly exceeding, and approximately equal to that of the whole nerve, were found.

Thus, nerves stretched post-operatively show a much greater relative elongation in the distal half of the peripheral stump. This is no doubt correlated with the formation of scar tissue and adhesions in the region of the suture line in resected and sutured nerves. In all the experimental animals the nerves at autopsy were found to lie in a dense scar filling the lower part of the popliteal space, and forming adhesions between the nerve and its bed. This scar was especially dense about the suture line of the external popliteal nerve.* Now, if this scar acted in such a way as to pin the nerve down at the suture line, it would produce precisely the distribution of elongations seen when the knee was extended. By far the greatest proportional elongation would occur distally—between the suture line and the point of muscle entry—and when this region had reached the limit of its extensibility, the general effect would be to pull the whole nerve, and the tissues to which it was adherent, downward slightly, thus producing a relatively smaller elongation of the central stump. The suture line of a post-operatively stretched nerve may thus be regarded as a 'fixed point', in the same sense that the point of muscle entry is fixed (*see* p. 357). It is less mobile than the rest of the nerve, and only moves when elongation of the nerve between it and the extending joint has reached a maximum.

* There was no post-operative infection in this series of experiments.

An additional confirmation of this hypothesis of the effect of adhesions at the suture line is seen in the case of Dog 20 (*see Table II*). In this animal the suture was made high up in the thigh, only 17 mm. distal to the sciatic notch. Thus, even if the nerve were fixed at the suture line, a considerable length of nerve would remain free distal to it. *Table II* shows that in this animal the nerve stretched extensively but approximately uniformly.

Post-operative nerve stretching thus does not normally elongate the nerve uniformly. Scar tissue 'fixes' the suture line, with the result that when the suture is made close to the extending joint in the lower third of the thigh, disproportionate tension is exerted on the more distal parts of the peripheral stump.

'Growth' of the Nerve.—If 'growth' (i.e., permanent increase in length) of the nerve takes place during post-operative stretching it would be revealed by the X-ray photograph. An X-ray photograph taken with the knee flexed after postural extension had been completed would show an increase in inter-clip distances compared with a photograph, also taken in flexion, before postural extension was begun.

Table III shows the inter-clip distances measured in the case of Dog 19 (*a*) at operation, (*b*) at plaster change before post-operative stretching was begun, (*c*) at plaster removal after post-operative stretching had been completed (in this animal the knee was extended by means of a turnbuckle), (*d*) at the final X-ray examination after the animal had been allowed to run free for 7 days, (*e*) at autopsy. Measurements (1), (2), (3), (4), (5) represent successive inter-clip distances passing down the nerve, beginning at the topmost clip; measurement (6) is the distance between the lowermost clip and the posterior border of the tibia. It will be seen from *Table III* that post-operative stretching brought about no permanent increase in either the inter-clip distances or in the distance between the lowermost clip and the posterior border of the tibia. Indeed, the clips nearest to the suture line (measurement 5) were closer together after post-operative stretching than before. This was probably a secondary effect of tensions exerted upon the scar tissue surrounding the nerve, since both clips were found to be still firmly attached to the nerve, and at their original distance apart when the nerve was freed from scar tissue at autopsy.

In the other animals similar effects were seen. During extension of the knee the clips moved apart, but when the knee was flexed again, they returned to their original positions. This effect is clearly shown by comparison of the two radiographs in flexion given in *Fig.* 375, A and C.

Table III.—Distances in Millimetres between the Silver Clips with the Knee in Flexion in Dog 19, Measured at Different Times before and after Stretching

	Measurement					
	1	2	3	4	5	6
Operation	10	26	20	22	10	8
Plaster change	10	26	21	21	11	8
Nerve stretched.....	.....	.....	.....	.....	.....	.....
Plaster removal	10	28	21	19	9	8
Final radiograph	11	25	21	19	8	9
Autopsy	10	27	24	21	9	7

Therefore, during the first 35 days after resection and suture the external popliteal nerve does not undergo 'growth' during post-operative stretching. However, it was found in Dogs 18, 20, 23, and 26 that a slight permanent increase took place during post-operative stretching in the distances between the two clips placed on either side of the suture line. The maximum increase, when the nerve was freed from scar tissue at autopsy, was found to be 9 mm. in the case of Dog 26. Histologically (*see* p. 364) this was shown to be due to a tearing apart of the stumps at the suture line, and not a result of 'growth' of the nerve. All these animals in which the nerve had elongated in the region of the suture line (*see Table II*) showed separation of the stumps histologically.

The most remarkable fact is that the distance between the lowermost clip and the tibial border (*see Fig.* 374, C) returns to its original value following an increase during post-operative stretching by as much as 387 per cent (*see Table II*, and *Table III*, measurement 6. Rupture of the lower 'fixed point' and evulsion of the nerve from the shank, therefore, does not occur. However, as already discussed (*see above*, p. 360), a large part of this excessive increase in length is probably made up by distraction of the muscles and fascia rather than by elongation of the nerve.

Histological Observations.—When the internal and external popliteal nerves were exposed, 35 days after operation, a considerable amount of scar tissue was found surrounding the two nerves in the region of the suture lines. The density of the scar varied in different animals, but it was always more dense round the external popliteal nerve, and invariably caused adhesions between the suture line and the fascial bed of the nerve. The peripheral stump was always more heavily

involved than the central, and in three cases (Dogs 16, 18, and 26) the scar was found to extend right down to the lower limit of the nerve in the thigh. The central stump was never involved

FIG. 376.—Photomicrograph of tip of central stump of unstretched nerve. Note small extent of retrograde degeneration. (Flemming-Weigert.) (24g. 9. 6.)

in scar tissue for more than about 2 cm. above the lesion.

The control suture made in the internal popliteal nerve always presented the same appearance at biopsy. The central and peripheral stumps were always of the same calibre, and there was a slight fusiform enlargement of the nerve at the suture line.

In the post-operatively stretched external popliteal nerve two types of suture line were seen. In Dogs 20, 23, and 26 there was some evidence of separation at the suture line, as shown by thinning of the nerve-trunk. In the other animals the stumps were approximately of the same calibre, but showed a difference from the internal popliteal control suture in that there was never a fusiform enlargement formed at the suture line, the nerve being very little thickened, if at all.

Histologically, considerable differences were seen between the internal popliteal nerves, which were sutured but not stretched, and the external popliteal nerves in which both suture and post-operative stretching had been performed. In the internal popliteal nerve degeneration and re-innervation took place in a perfectly normal manner. In the central stump gross retrograde degeneration in no case extended more than 5 mm. above the level of the lesion (*Fig.* 376), so that 1 cm. above the lesion the nerve at 35 days was found to contain a full complement of normal myelinated fibres (*Fig.* 377).

In the external popliteal nerves a much more extensive retrograde degeneration took place. In the different animals it varied in extent, but in Dog 24, in which the central stump was elongated by 12 per cent (*see Table II*), and in all the animals where an elongation of 11 per cent or more had taken place, retrograde degeneration involved every fibre for at least 3 cm. above the lesion, and its effects could be observed as high as 9 cm. above the lesion. Compared with the unstretched internal popliteal nerve in the same animal (*Fig.* 377), the central stump 1 cm. above the lesion contained no nerve-fibres (*Fig.* 378); 3 cm. above the lesion there were only a few small myelinated fibres, restricted to one side of the nerve (*Fig.* 379); 5 cm. above the lesion there were more fibres, but they were all small and irregularly distributed (*Fig.* 380); as high as 9 cm. above the lesion the fibres were still smaller than normal, and the nerve contained patches of fibrous tissue in which there were no fibres (*Fig.* 381). However, in Dogs 23 and 26, in which the central stump was elongated by only 6 per cent (*see Table II*), none of this excessive retrograde degeneration took place. New fibres were found right down to the tip of the central stump, and in the case of Dog 23 in the central end of the peripheral stump (*Fig.* 382). Thus, elongation by as little as 6 per cent does not involve damage to the central stump, while elongation of 11 per cent or more causes extensive degeneration.

While massive degeneration in the central stump is the immediate effect of severe stretching

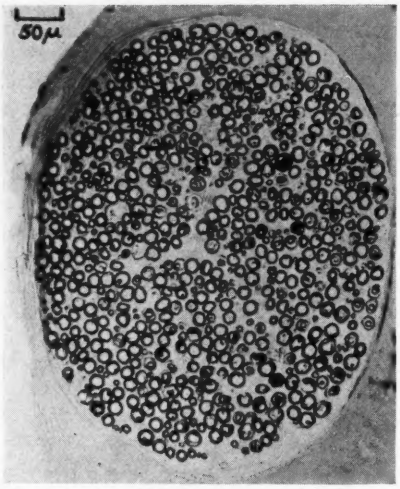


FIG. 377.—Photomicrograph showing myelinated fibres in transverse section of unstretched nerve 1 cm. above suture line. Note normal nerve-bundle and profusion of myelinated fibres. (Flemming-Weigert.) (24g. 2. 2.)

of sutured nerves, the course of this degeneration itself appears to be abnormal. Thirty-five days after operation the peripheral stump of both the internal popliteal (sutured but not stretched) and the external popliteal (sutured and stretched) contained a great many macrophages filled with myelin remains (*Figs.* 383, 384), and the internal popliteal contained a number of new, small

medullated fibres. Stretching was begun 14 days after operation, and was the cause of the retrograde degeneration in the central stump of the external popliteal nerve. Therefore, this degeneration

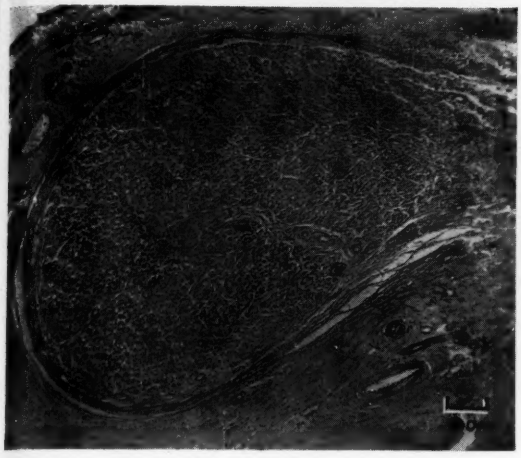


FIG. 378.—Photomicrograph of transverse section of stretched nerve 1 cm. above suture line. There are no myelinated fibres. Note thickening of epineurium. (Flemming-Weigert.) (24c. 1. 4.)

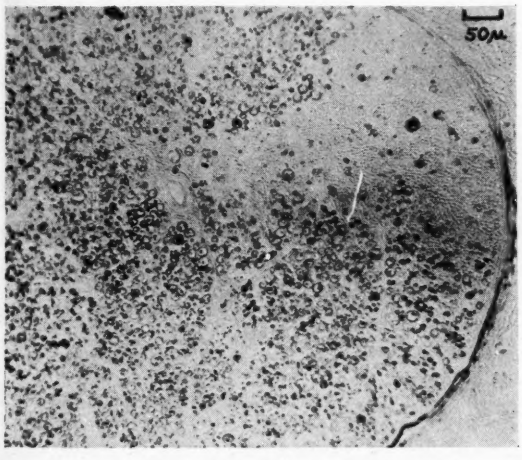


FIG. 380.—Photomicrograph of transverse section of stretched nerve 5 cm. above suture line. Small myelinated fibres, but still large spaces without fibres. (Flemming-Weigert.) (24e. 1. 1.)

can only have been in progress for 21 days, and the central stump of the external popliteal nerve should contain more macrophages filled with myelin remains than either its own peripheral stump or that of the internal popliteal nerve, where degeneration has been in progress for 35 days. Although occasional macrophages were found in the central stumps of stretched nerves at this time, and there were also many empty 'digestive chambers' (*Fig.* 386), very few myelin remains could be found at any level in the central stump. At 2 cm. above the lesion the nerve contained practically none, with a few normal myelinated fibres at one side of the nerve (*Fig.* 385). However, an increase in the number of Schwann nuclei took place in the central stump, which is a characteristic response on the part of a nerve which is undergoing Wallerian degeneration (*Fig.* 389). All this suggests either (*a*) that the process of

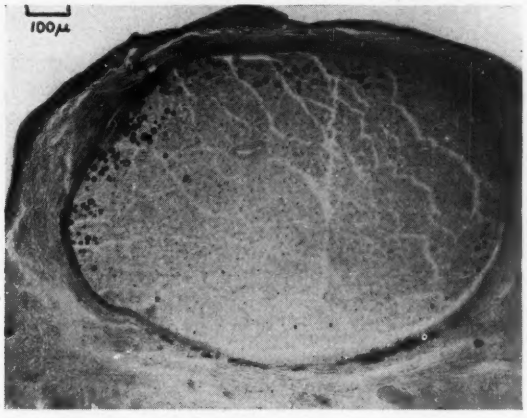


FIG. 379.—Photomicrograph of transverse section of stretched nerve 3 cm. above the suture line. A few small myelinated fibres at one side of the section. (Flemming-Weigert.) (24d. 1. 3.)

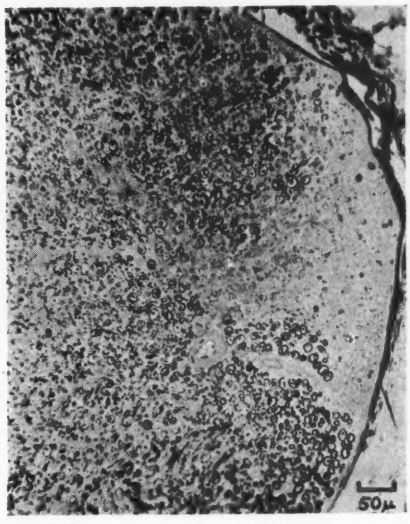


FIG. 381.—Photomicrograph of transverse section of stretched nerve 9 cm. above suture line. Many myelinated fibres, but still one area of fibrosis. (Flemming-Weigert.) (24f. 1. 2.)

myelin breakdown and removal in the central stump of post-operatively stretched nerves does not follow the normal course of Wallerian degeneration, or (*b*) that stretching in some way greatly accelerates the removal of myelin from the central stump.

Multiplication of Schwann nuclei occurs in stretched nerves, both in the peripheral stump and in the degenerated region of the central stump (*Figs.* 388, 389). Although careful counts have not been made, the stumps of a stretched nerve 35 days after operation appear to contain more nuclei per unit area of the section than an

unstretched stump of the same age (compare *Figs.* 387 and 388). Stretching of a degenerating length of nerve may therefore result in increased multiplication of the Schwann nuclei in the peripheral stump and in the degenerated zone of the central stump (*Fig.* 389). However, at this stage it is often difficult to make an absolute distinction between Schwann and fibroblast nuclei (*see* Holmes and Young, 1942, p. 72) and some of the large numbers of extra nuclei seen may belong to proliferated fibroblasts. The fact that extensive production of collagen is also a marked feature of the histology of stretched nerves (*see below*, and also Highet and Holmes, 1942) lends weight to this conclusion.

None of the unstretched internal popliteal nerves showed any separation at the suture line. At the suture line there was some disturbance of the pattern of the nerve (*Fig.* 390), owing to the presence of the suture material and the reaction to it, but no separation between the bundles of the central and peripheral stumps was found. Three of the stretched external popliteal nerves also showed no separation at the suture line (Dogs 16, 19, and 24), and these were the three animals which showed no elongation of the segment of nerve, including the actual region of suture. The only difference seen between these nerves and those which were not stretched, was the occurrence of extensive degeneration in the central stump, and the increase in the amount of fibrous tissue at the suture line which accompanied post-operative stretching (*Fig.* 391). The other four animals, in which a permanent increase occurred during post-operative stretching in the distance between the clips on either side of the suture line, showed a separation of the stumps at the suture line varying from 3 mm. to 4 mm. in Dog 23, to 9 mm. in Dog 26. However, in all cases there was not an absolute gap between the stumps, the gap being bridged by longitudinally orientated bands of Schwann cells and fibroblasts connecting the central to the peripheral stump (*Fig.* 392). In Dog 23, where only a small percentage elongation was applied to the central stump, no excessive retrograde degeneration had taken place (*see above*, p. 362); new fibres were found to have reached the peripheral stump via the short strand between the stumps. In no other stretched nerve were any fibres found in the peripheral stump. In Dog 26, owing to the small amount of retrograde degeneration which took place, fibres were found right up to the tip of the central stump,

FIG. 382.—Photomicrograph of longitudinal section of region of scar in an animal in which the central stump was only slightly elongated. Note a few, thin, nerve-fibres. (Bodian.) (23d. 6. 4.)

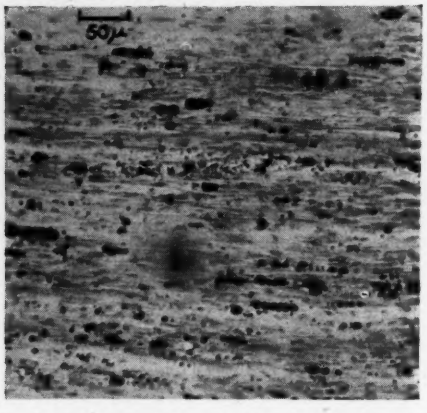


FIG. 384.—Photomicrograph of longitudinal section of peripheral stump of stretched nerve 7 mm. below suture line. Note myelin remains. (Cf. *Fig.* 010.) (Flemming-Weigert.) (24b. 2. 2.)

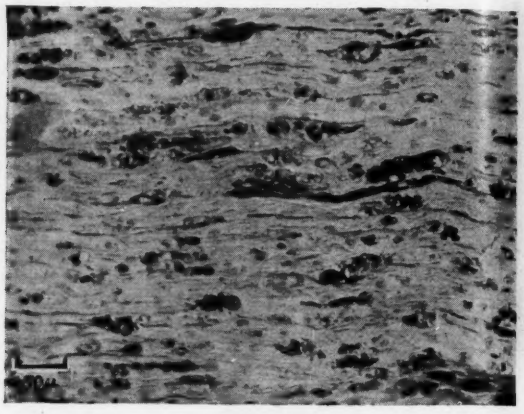


FIG. 383.—Photomicrograph of longitudinal section of part of peripheral stump of sutured but unstretched nerve. Note myelin remains and new myelinating fibres. (Flemming-Weigert.) (24h. 3. 3.)

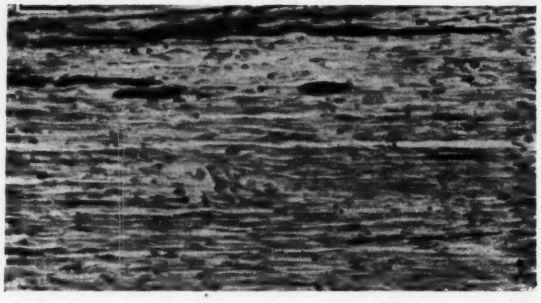


FIG. 385.—Photomicrograph of part of central stump of stretched nerve 3 cm. above suture line. Longitudinal section. Note small number of myelinated fibres, and an almost complete absence of myelin remains. (Flemming-Weigert.) (24c. 2. 3.)

but in this animal such a large separation of the stumps at the suture line took place that no fibres had reached the peripheral stump 35 days after operation.

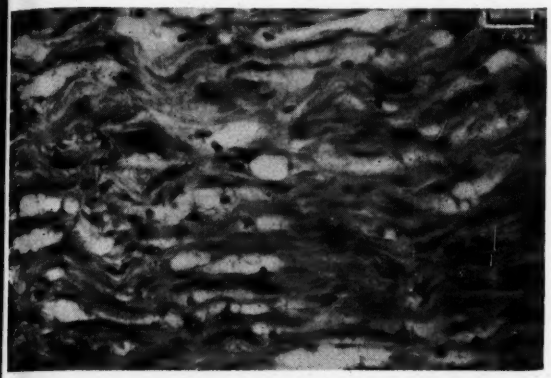


FIG. 386.—Photomicrograph of longitudinal section of part of central stump of stretched nerve 2 cm. above suture line. Note spaces in nerve which originally contained macrophages. (Masson.) ($19c_2$. 6. 1.)

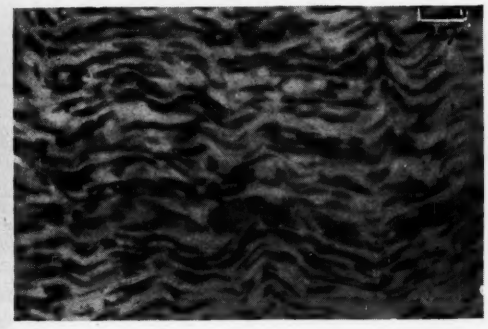


FIG. 388.—Photomicrograph of longitudinal section of part of peripheral stump of stretched nerve. Note many nuclei. (Hæmatoxylin and eosin.) (18d. 1. 2.)

By far the most important difference between post-operatively stretched and unstretched nerves is seen in the amount of collagenization which goes on in the former. Throughout the peripheral stump and the degenerated zone of the central stump of a stretched nerve patches of fibroblasts surrounded by masses of fresh collagen were seen within the nerve-bundles, seriously disturbing the pattern of the nerve (*Fig.* 393). There was also an increase in the epineurial connective tissue, compared with normal nerve (*see Figs.* 378, 379), some of which could be seen occasionally actually merging with the nerve-bundles (*Fig.* 378). By far the most extensive collagenization was seen in the most distal segment of the peripheral stump, which *Table II* shows to be the region where the nerve stretches to the limit of its extensibility. In this region the nerve-bundles contained many large lacunæ (*Fig.* 394) in which fibroblasts could often be found laying down fibrous tissue (*Fig.* 393), and some of the bundles had in this way been partly obliterated.

Moreover, this region of the nerve is the only one in which direct evidence of the rupture of endoneural or ' Schwann ' tubes (*see* Holmes and Young, 1942) as a result of stretching could be

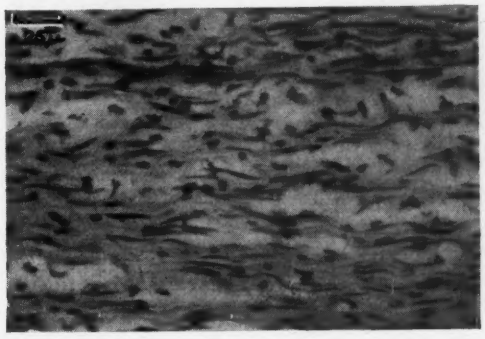


FIG. 387.—Photomicrograph of longitudinal section of part of peripheral stump of unstretched nerve. Note Schwann nuclei. (Hæmatoxylin and eosin.) (18f. 1. 2.)

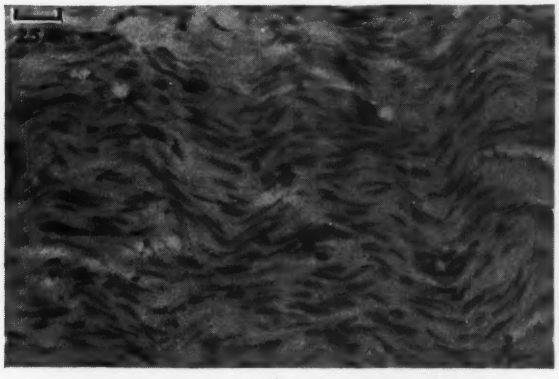


FIG. 389.—Photomicrograph of longitudinal section of part of central stump of stretched nerve 2 cm. above suture line. Note multiplied Schwann nuclei. (Hæmatoxylin and eosin.) ($19c_2$. 1. 1.)

found. Individual groups of tubes, mostly at the edges of bundles (*Fig.* 395), and occasionally whole small bundles, showed evidence of having been forcibly torn apart, and in the spaces between the torn ends fibroblasts were found laying down fibrous tissue. The fibroblast reaction which is so marked a feature of nerve stretching is probably a reaction directed towards the repair of the tissue directly damaged by the stretching.

In the region where very severe stretching had occurred the results of damage to the blood-vessels could also be seen. Places were found where capillaries had been broken apart, releasing a shower of erythrocytes into the tissue (*Fig.* 395), and also where a blood-vessel, entering a funiculus through its peripheral wall, had been broken off short, probably as a result of shearing stresses set up by unequal elongation of the perineurium and the bundle itself (*Fig.* 396). Erythrocytes found amongst the bundles of nerve-fibres indicated that the hæmorrhages were of recent origin. Bleeding taking place as long before autopsy as at the original postural extension by which

FIG. 390.—Low-power photomicrograph of junction of unstretched nerve. Note apposition of stumps. (Masson.)

FIG. 391.—Low-power photomicrograph of junction of stretched nerve in which the stumps did not separate. Note fibrosis. (Masson.) (19d. 3. 7.)

FIG. 392.—Low-power photomicrograph of the junction in a stretched nerve in which the stumps became separated. The large spaces mark the position of originally closely apposed stitches. (Masson.) (26d. 4. 2.)
In *Figs.* 390–392 the central stump is uppermost.

post-operative stretching was brought about (21 days earlier), would not reveal itself at autopsy by the presence of erythrocytes in the nerve. Thus, if these appearances are not the result of operative trauma at autopsy, movements of the limb, continually stretching and relaxing the nerve to more than a normal extent, must be the cause of recurrent hæmorrhages in the nerve quite a long time after the original post-operative stretching has been completed. However, at 35 days most of the nerve is abundantly supplied with undamaged blood-vessels. No trace was seen in the vessels of the intimal fibrosis described by Highet and Holmes (1942) in human nerves. However, at 35 days it is probably too early to demonstrate such changes. Small lymphoid accumulations around the vessels were, however, occasionally seen, probably early indications of the persistent inflammatory changes seen by these authors.

Proximal to the hip-joint the nerve contained occasional patches of degeneration as revealed by groups of multiplied Schwann nuclei, right up to the sciatic plexus. In the animals where measurements made on the radiographs showed that the nerve above the hip-joint had not been severely stretched, the plexus, the dorsal root ganglia, the roots, and the cord showed no evidence of any damage.

Severe stretching of a sutured nerve can thus result in the following types of damage: (*a*) Separation of the stumps at the suture line; (*b*) Excessive abnormal degeneration in the central stump; (*c*) Rupture of bundles of fibres in the region where stretching is most severe; (*d*) Extensive collagenization both outside and inside the funiculi, resulting in considerable disruption of the pattern of the nerve, and most intense where the severest tensions had been applied; (*e*) Rupture of blood-vessels within the nerve.

Comparison of Rapidly and Gradually Stretched Nerves.—The results given by Dogs 16, 18, and 19, in which the nerves were gradually stretched by means of a turnbuckle plaster, showed very little difference from Dogs 20, 23, 24, and 26, which were allowed to stretch the nerve rapidly by means of their own movements.

Dogs 16 and 19 showed no separation of the stumps at the suture line, but in Dog 18 wide separation had taken place, indicating that gradual stretching does not necessarily prevent separation at the suture line. However, Dogs 20, 23, and 26, in which stretching was rapid, all showed separation at the suture line.

Gradual stretching was accompanied by just as much scar formation and disproportionate elongation of the peripheral stump as rapid stretching (*see Table II*). Moreover, Dogs 16, 18, and 19 showed the same sort of histological damage within the nerve as did the animals in which the sutured nerve had been rapidly stretched. Retrograde degeneration of gross proportions occurred in the central stump, and

there was collagenization and blood-vessel damage. Gradual stretching is therefore not less damaging than rapid stretching, although the greater frequency of separation at the suture line which took place following rapid stretching is a suggestive difference. However, it will be noted that even in those experiments in which the nerves were gradually stretched the limb was extended fully in a relatively short time (14 days). An even more gradual stretching (full limb extension in 6 weeks—*see* Highet and Holmes, 1942) is normally employed in human cases, and this may result in slightly less damage.

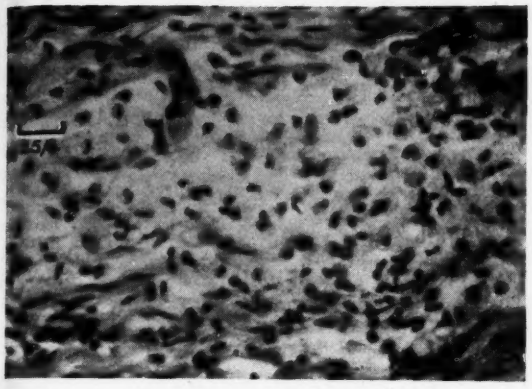


FIG. 393.—Photomicrograph of longitudinal section of distal part of peripheral stump of stretched nerve showing patch of fibrosis. (Masson.) (26f$_2$. 5. 3.)

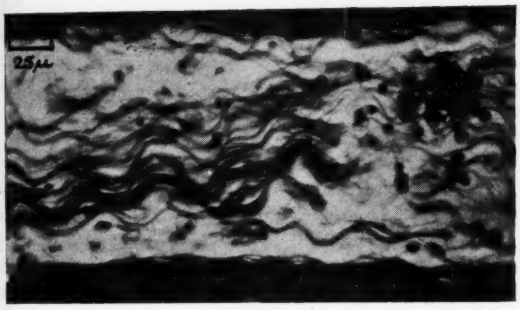


FIG. 395.—Photomicrograph of longitudinal section of most distal part of peripheral stump of stretched nerve, showing a small funiculus with ruptured Schwann tubes, and the hæmorrhage resulting from the rupture of a small capillary. (Mallory.) (26f$_2$. 6. 6.)

DISCUSSION

The results which have the most important application to the surgery of peripheral nerve injuries in man are: (*a*) the fact that histological damage follows extensive post-operative stretching of sutured nerves; (*b*) the fact that adhesions cause the suture line to act as a fixed point, so that when the suture is made close to a joint the peripheral stump is subjected to greater tension than the central; (*c*) the fact that permanent extension of the nerve does not take place, at any rate in the early stages, each extension of the joint applying the same tension to the nerve as that which accompanied the original post-operative stretching.

The resections made in these experiments (2·5–4·0 cm. in the dog) correspond to the gaps of 10–15 cm. occasionally closed by suture

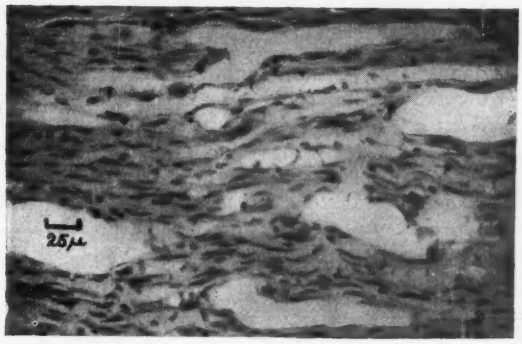


FIG. 394.—Photomicrograph of longitudinal section of severely stretched distal part of peripheral stump of stretched nerve. Note large lacunæ disturbing pattern of nerve. (Hæmatoxylin and eosin.) (19h. 2. 7.)

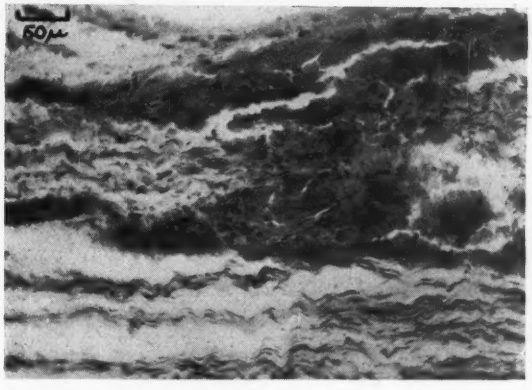


FIG. 396.—Photomicrograph of longitudinal section of most distal part of peripheral stump of stretched nerve, showing hæmorrhage resulting from rupture of a large vessel at the point where it enters a funiculus. (Hæmatoxylin and eosin.) (20b. 1. 4.)

followed by post-operative stretching in human nerves. In the dog this amount of elongation, which caused the mobilized length of nerve to extend by 24–42 per cent, resulted in extensive, abnormal, retrograde degeneration, and collagenization in the central stump, together with œdema, collagenization, and blood-vessel damage in the peripheral stump. It may be concluded that similar changes will follow extensive post-operative stretching of human nerves. Indeed, Highet and Holmes (1942) found extensive degeneration of nerve-fibres, arterial and inflammatory changes, and massive intraneural fibrosis in cases in which no recovery occurred after extensive post-operative stretching of the nerve.

It is easy to see how such changes will tend to prevent complete functional recovery. The fibrosis which occurs in both stumps will result in the blockage of pathways and the disruption of the pattern of the nerve, and where extensive

retrograde degeneration has occurred fibrosis will have proceeded farther, and so produced a more extensive block in the peripheral stump before fibres reach peripheral levels. Thus the whole result of the damage will be to decrease the chances of an adequate number of fibres reaching correct endings in the periphery and producing functional recovery. Functional recovery, especially in man, where the functions lost are delicate and therefore need a greater number of mature fibres (*see* Gutmann, Guttmann, Medawar, and Young, 1942) for their restoration, will be both delayed and of poor quality, if it occurs at all. The ease with which a large gap can be dealt with by suture and stretching is a great inducement to its performance, and the only present alternative to this operation is a cable autograft (*see* Sanders, 1942). However, the results to date of nerve-grafting in war injuries have been poor. It is thus necessary to consider whether the damage following the use of post-operative stretching to close a particular gap is likely to result in a worse recovery than that following a nerve-graft, and on this basis the surgeon must decide whether or not to perform the operation. In order that he may make these decisions further information is needed, both on the effects of post-operative nerve stretching in man, and on the prospects of nerve-grafting as a method of nerve repair. With the success of thin autografts in the facial nerve and in the nerves of the hand, and with the advent of new technique which renders more easy the fixing of grafts, this method may yet prove of value (*see* Sanders, 1942).

The present experiments indicate that there is probably an upper limit to the size of gap that can be overcome by post-operative stretching in man and yet be compatible with recovery. From a review of cases, Highet and Holmes (1942) indicate that a possible value for the limit is about 11 cm. for the lateral popliteal and 9 cm. for the median nerve. However, when the suture is made close to a joint, and the length between the suture line and the extending joint is small (e.g.., peroneal at the knee), there is no guarantee that adhesions forming about the suture line will not make it a fixed point, and cause excessive tension to be applied to the peripheral stump, with consequent fibrosis, even when quite a mild elongation is applied to the whole nerve. So in operations involving post-operative nerve stretching it becomes essential (*a*) to guard against the formation of adhesions at the suture line—wrappings of a material such as amnioplastin (Rogers, 1941) may be of use in this connexion; (*b*) to make the suture as far away as possible from the joint by whose movement elongation of the nerve is brought about, so that the elongation is spread over the greatest length of peripheral stump.

The present experiments indicate that post-operative stretching of a nerve does not result in its permanent elongation, at any rate in the early stages, and each extension of the limb applies the same stresses to the nerve as accompanied the original stretching. Where the original extension produced damage, subsequent extensions will tend to repeat that damage. Thus it is probable that the factors which produce fibrosis are still active after stretching has been completed for the first time, and will continue to produce damage. Fibroblasts have a well-marked property of orientating themselves along lines of stress, and the nerve may well become a focus for the deposition of fibrous tissue, the parts of it where the most severe stretching has occurred becoming converted into fibrous strands. This seems to have occurred in one of the cases described by Highet and Holmes (1942). Hence traction injury after suture differs from the sudden traction lesion of normal nerves (e.g., birth palsies) in that the damage produced tends to be both repetitive and cumulative, at any rate for some time. This cumulative effect is likely to have a profound influence upon functional recovery.

Rapid stretching was not followed by any more damage than a more gradual stretching, though the rate at which the nerves were stretched in the present experiments was greater than in human cases (*see above*, p. 367). The degree of damage appears to depend more upon the total tension applied. Moreover, since the nerves did not 'grow' the damage to them was repeated in subsequent extensions of the limb. Nevertheless, three out of four animals with rapidly stretched nerves showed separation of the stumps at the suture line, while only one out of three with gradually stretched nerves showed such a separation. The suture line may thus be less resistant to rapid than to gradual stretching. However, the work of Miller (1921), who tested the strength of suture lines of various ages and found that the strength of the suture line reaches a maximum three weeks after operation, suggests that the relatively high frequency of separations at the suture line found in our experiments was due to the short period of delay (14 days) before stretching was begun.

Apart from the cases of Stookey (1922) and Highet and Holmes (1942) already mentioned, it is difficult to find direct confirmation of these results in the clinical field. Suture followed by post-operative stretching has frequently been used to close extensive gaps in man (*see* Forrester-Brown, 1921; Babcock, 1927), but it is often difficult to be sure from the clinical reports whether recovery took place. Moreover, where tables of recoveries are given, the extent of the gaps closed is frequently not mentioned. The whole problem of post-operative nerve stretching is in need of extensive clinical investigation, principally to discover accurately the limits to the gaps that can be dealt with by this method in man, and still be followed by a good recovery, and also the relation of nerve stretching to other factors which interfere with the progress of

recovery, such as infection and delay of suture (*see* Holmes and Young, 1942). It is important that such an investigation should be made to decide future policy with regard to the repair of peripheral nerve injuries.

SUMMARY

1. Gaps in the external popliteal nerve of the dog following extensive resection of the nerve in the thigh were closed by flexion of the knee and suture of the stumps with the limb in this position. After keeping the knee in flexion for 14 days by means of a plaster coat, the nerve was stretched by extending the knee, either (*a*) gradually by means of a turnbuckle plaster, extension being completed in 14 days, or (*b*) rapidly, through the animal's own movements. The site and extent of stretching was determined by means of a line of silver clips placed along the nerve at operation, and photographed by X rays before and after stretching was brought about.

2. In the normal animal some elongation of the nerve over its whole length from the sciatic plexus to its entry into the shank musculature accompanies extension of the knee. By far the greatest part of the increase in length of the course of the nerve during knee extension in the normal animal, is made up by the straightening out of the tortuosity of the nerve.

3. When gaps have been closed by flexion of the knee, the extra distance is made up by elongation of the nerve. Straightening out of tortuosity plays only a minor part.

4. The elongation produced in this way was not distributed uniformly along the length of the nerve in the thigh. Scar tissue formed around the suture line bound the nerve to its bed, so giving a secondary fixed point, and disproportionate elongation of the peripheral stump occurred. The most distal segment of the peripheral stump stretched to the limit of its extensibility when the suture was made low in the thigh.

5. After such stretching the nerve returned to its original length with each subsequent flexion of the knee. Permanent elongation of the stretched segment of the nerve does not, therefore, take place during the first 35 days after operation.

6. Elongation of nerves by amounts of the order investigated produces histological damage of the following kinds: (*a*) extensive, abnormal degeneration in the central stump; (*b*) where the suture line is not bound down by scar tissue, separation of the stumps can take place; (*c*) rupture of Schwann tubes in the regions where stretching is most severe; (*d*) extensive œdema and fibrosis both without and within nerve bundles, causing considerable disruption of the pattern of the nerve. All these factors will tend to reduce the chances of a recovery of good quality.

7. Rapid nerve stretching did not cause any more damage than slow stretching, except, perhaps, in so far as separation at the suture line occurred more frequently.

8. The bearing of these results on the post-operative stretching of human nerves is discussed.

We wish especially to thank Dr. A. E. Barclay and Miss M. M. L. Pritchard, of the Nuffield Institute for Medical Research, and their technician, Mr. M. Tuckey, by whose kind help the X-ray photographs were made possible. We also owe our thanks to Professor H. J. Seddon and Mr. J. Z. Young for reading and criticizing the manuscript.

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REFERENCES

BABCOCK, W. W., *Surg., Gynecol. and Obst.*, 1927, **45**, 364.
BARON, A., and SCHEIBER, W., *Münch. med. Woch.*, 1918, **65**, 446.
FORRESTER-BROWN, M., *Orthopædic Surgery of Injuries* (Jones), 1921. Oxford.
GUTMANN, E., GUTTMANN, L., MEDAWAR, P. B., and YOUNG, J. Z., *Jour. of Exper. Biol.*, 1942, **19**, 14.
GUTTMANN, L., *Brit. Jour. Surg.*, 1943, **30**, 370.
HIGHET, W. B., and HOLMES, W., *Ibid.*, 212.
HOLMES, W., and YOUNG, J. Z., *Jour. of Anat.*, 1942, **77**, 63.
MILLER, E. M., *Arch. of Surg.*, 1921, **2**, 167.
MITCHELL, W., *Injuries of the Peripheral Nerves*, 1872. Philadelphia.
NAFFZIGER, H. C., *Surg., Gynecol. and Obst.*, 1921, **32**, 193.
PLATT, H., *The Surgery of Peripheral Nerve Injuries of Warfare: Hunterian Lecture*, 1921. Bristol.
PLATT, H., and BRISTOW, W. R., *Brit. Jour. Surg.*, 1924, **11**, 535.
ROGERS, L., *Brit. Med. Jour.*, 1941, **1**, 587.
SEDDON, H. J., personal communication.
STILES, H., *Orthopædic Surgery of Injuries* (Jones), 1921. Oxford.
STILES, H., and FORRESTER-BROWN, M., *Injuries of Peripheral Nerves*, 1922. Oxford.
STOOKEY, B., *Surgery and Mechanical Treatment of Peripheral Nerves*, 1922. Philadelphia.
TAKIMOTO, G., *Mittl. a. d. Fakult. med. der. k. Univ., Tokyo*, 1916–7, **16**, 73.

EXPERIMENTAL STUDY ON NERVE SUTURE WITH VARIOUS SUTURE MATERIALS

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In spite of very wide experience of nerve suture obtained during and after the last war, there is yet no uniformity of opinion as to the most satisfactory suture material. Amongst the various kinds of material, the suitability of catgut has been discussed most frequently. Greenfield and Sargent (1919) found that catgut impregnated with any chemical such as chromic or tannic acid elicits a very strong cellular reaction, and has a bad absorption. Plain catgut also produces a strong cellular reaction; it was, however, found to be absorbed more quickly than silk or linen thread. For this reason many authors recommend plain catgut as the best material for nerve sutures (Maingot, 1936; Romanis and Mitchiner, 1937; Handfield-Jones and Porritt, 1938; Souttar, 1941). Thorek (1940) recommends even chromic catgut, although only for epineural suture. On the other hand, Babcock (1927) found in a case of nerve suture carried out with chromic catgut pockets of leucocytic infiltration and liquefaction necrosis around the sutures which had been inserted several months previously. Other authors, e.g., Stiles and Forrester-Brown (1922), Jefferson (1932), and Platt (1934), also disapproved the application of catgut containing any chemical. The Medical Research Council (1922) expressed doubts whether the better absorption of plain catgut compensates the disadvantage of its stronger cellular reaction. As to the suitability of silk or linen thread, many authors prefer impregnated silk or linen thread, particularly black silk, to plain white silk. Another point of discrepancy is whether waxed or unwaxed silk or linen thread is more suitable for nerve suture. Huber (1919) emphasized that waxed silk greatly facilitates the application of the suture. Sargent and Greenfield (1919) found, however, that waxed silk or linen thread gave rise to more small cellular infiltration than plain silk or thread.

Compared with catgut and silk, other kinds of material, such as metal, hair, and sticking materials are of subordinate significance for nerve suture in man, although some of them, such as living muscle varnish (Ballance, Colledge, and Bailey, 1926), concentrated plasma (Young and Medawar, 1940), and horsehair (R. Kennedy, 1918), have been proved satisfactory in animal experiments. No animal experiments, on the other hand, have been published about the suitability of woman's hair, which was found satisfactory by Foerster (1929) for nerve suture in man.

On account of the uncertainty and discrepancy of opinion it seemed worth while to reconsider the question of suitability of various kinds of material for nerve suture by the following experiments.

METHOD AND TECHNIQUE

In 24 rabbits the tibial nerves were cut on either side in the middle of the thigh under nembutal or ether anæsthesia, and a primary suture was carried out with different materials. In a number of cases the nerve was crushed for about 10 mm. of its length and then cut in the middle of the crushed region. In the great majority of cases re-junction of the stumps was made by end-to-end suture; in a few cases the methods of *suture à distance* (Asaky) and nerve-flaps (Létiévant) were employed. The silk and catgut used were of the thinnest size obtainable, but they were thicker than hair. Only the smallest round-bodied needles were used, which were of the 'end-threaded type', except those used for woman's hair. Because of the small calibre of the rabbit's tibial nerve only one suture was inserted. The sutures were not confined strictly to the epineurium; nearly all of them were more or less transfixing sutures. No special precautions were taken to restrict the activity of the operated limbs in the days following the operation. After a period, usually of 15 or 25 days following operation, a biopsy was done under nembutal anæsthesia. After measuring the first reflex response to pinching below the junction in the peripheral stump in order to judge how far from the point of junction regenerating fibres had arrived, as described by Young and Medawar (1940), the nerve was taken out at the level of the junction and fixed and embedded for Bodian staining (1936). The histological criterion for the suitability of the various kinds of suture material was the degree of fibrous and cellular reaction around the stitch. Three degrees of reaction were distinguished: F^1 = no or slight fibroplastic reaction; F^2 = distinct fibrous capsule around the stitch; F^3 = extensive fibrosis around and spreading away from the stitch; C^1 = no or minute cellular reaction; C^2 = stronger cellular reaction around the stitch; C^3 = strong cellular reaction around and spreading away from the stitch. As the closeness of apposition was not equally successful in all cases, three degrees were distinguished: J^1 = optimal junction; J^2 = stumps nearly or quite opposed, but with suture material and other interference between the ends; J^3 = definite gap between stumps bridged by fibrous or Schwann tissue.

The various kinds of suture material used in the experiments were:—

1. *Catgut.* Only plain sterilized catgut was used, as, according to Sargent's and Greenfield's experimental work, and to the statement of

authors with great clinical experience on this subject (Babcock, Jefferson, Platt), catgut impregnated with chromic acid or any other chemical can be considered as a bad form of nerve suture.

2. *Silk.* According to the literature there is no obvious difference in suitability between silk and linen thread. Therefore, only different kinds of silk were used—plain white silk, unwaxed black and green silk, and waxed black silk.

3. *Woman's hair.* Sterile brown hair (natural colour) taken from two women was used. The hair was sterilized by boiling for 10 minutes and afterwards keeping it in 70 per cent alcohol for 27 hours. Even sterilization in 70 per cent alcohol without boiling has proved satisfactory for nerve suture in rabbits.

Table I.—Results of Nerve Suture with Various Materials (*see* text)

Suture Material	Rabbit No.	Days	Junction	Fibrous Reaction	Cellular Reaction
Catgut	109*a*	25	1–2	1	3
	184	25	2	1	2
	185*a*	25	2	1	3
	358*c*	23	2	2	3
	359*a*	25	2	1	2
	88*a*	25	2–3	1	3
	358*b*	23	2	1–2	3
	357*a*	25	1–2	1–2	
	357*b*	25	1–2	1–2	3
	359*b*	25	—	1–2	3
	359*c*	25	—	2	3
White silk	122*b*	7	1–2	1–2	2
	155*d*	25	1	1	1
	261*a*	25	2	1	2
	88*a*	25	1–2	1–2	1
	261*d*	25	2	2–3	1
	134*a*	70	2	3	1
Black silk	75*b*	15	1–2	2	1
	78*a*	15	1–2	1–2	1
	110*c*	25	2	2	2
	96*b*	17	2	2	2
Black waxed silk	517*a*	19	1–2	2–3	2
	517*b*	19	1–2	2–3	1–2
	518*a*	26	3	2–3	2
	518*b*	26	2–3	2–3	2
Green silk	380*c*	15	2–3	2	3
	379*a*	15	—	2	3
	378*a*	15	—	2	1
Woman's hair	122*a*	7	1	1	1
	110*a*	25	1	2	1
	155*a*	25	1	1	1
	109*c*	25	1–2	1	1–2
	185*c*	25	1	1–	1–2
	156*a*	52	1	1	1
	321*a*	10	1–2	2	1
	156*c*	52	1–2	1	1

RESULTS

Table I demonstrates the results obtained with catgut sutures. These results are uniform regardless of the kind of junction performed. There was in all cases a very marked cellular reaction. The mesoblastic cell reaction usually consisted mainly of lymphocytes. This cellular reaction was always particularly marked around the catgut; it spread, however, away from the stitch in all directions, thus filling up more or less the cross-section of the nerve. This is shown in *Case* 185*a*, in which the catgut suture was inserted 25 days previously (*Fig.* 397). In another case (*Case* 359*a*) in which the suture was inserted mainly in the epineurium, a big unilateral bulb was formed by the great cellular reaction around the stitch (*Fig.* 398). Even in this case the cellular reaction also involved the middle part of the cross-section. In the majority of cases there was an increased formation of blood-vessels at the border of the area of cellular reaction. A particularly extensive cellular reaction was found in those cases in which a flap operation was carried out

(*Cases* 357*a*, *b*, and 358*a*). In some sections of the *Case* 357*b*, in which a flap of 20 mm. length from the peripheral stump was joined with the distal end of the central stump, the cellular reaction involved the whole cross-section. In other sections of the same case the outgrowing fibres from the central stump were seen passing through a narrow space of the cross-section left free by the cellular reaction. In *Case* 359, in which a *suture à distance* was made, the insertion points of suture of the central, and even more of the peripheral stump, showed a big cellular reaction. The tissue between two stumps containing the catgut bridge also showed enormous cell-collections surrounding the catgut pieces. No nerve-fibres were seen in this strand.

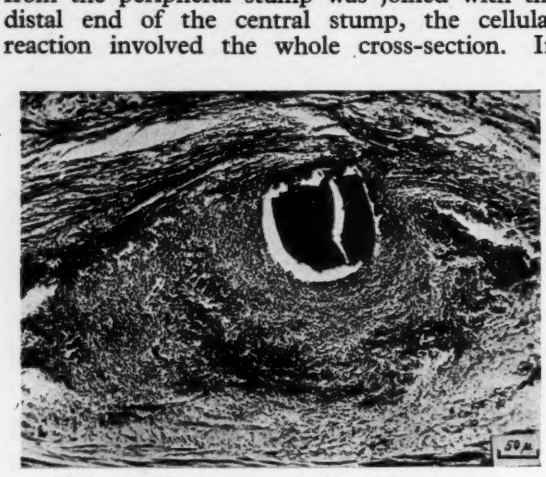

FIG. 397.—Catgut suture, 25 days. Very marked cellular reaction within the cross-section.

FIG. 398.—Catgut suture, 25 days. Very marked cellular reaction around the stitch involving the cross-section.

Contrasting with the marked cellular reaction, the fibrous reaction was small or moderate in the majority of cases. In no case was the catgut completely absorbed after a period of 25 days following operation. The catgut remnants themselves were swollen, thus definitely increasing the obstacle which the cellular reaction makes to the axons.

The results obtained with silk material are also shown in *Table I*. White silk elicits some reaction both fibrous and cellular. This reaction was found very slight in *Case* 155*d* 25 days after suture of the cut tibial nerve with a satisfactory junction (*Table I*). The fibrous reaction around the stitches can be, however, considerable, and it can spread away from the stitch for some distance. This was seen in *Case* 261*d*, 25 days after a moderate junction of the tibial nerve which was crushed before section (*Fig.* 399). In this case there was also a moderate cellular and vascular reaction. In the majority of silk sutures the cellular reaction was very slight, in contrast to the strong reaction set up by catgut. In *Case* 134*a* the silk was removed by giant cells

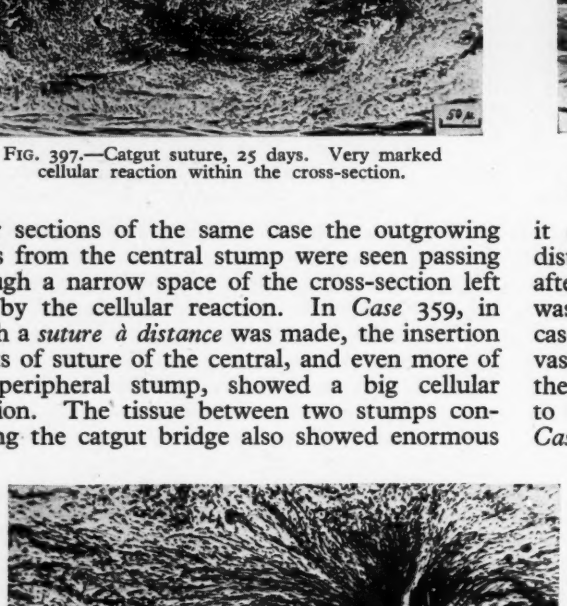

FIG. 399.—White silk suture, 25 days. Considerable fibrous reaction, moderate cellular and vascular reaction around stitch spreading away for some distance.

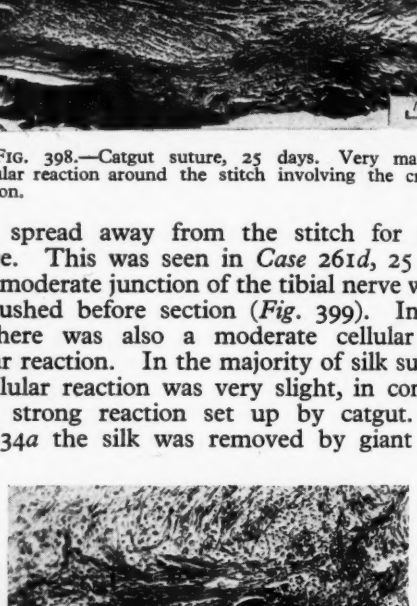

FIG. 400.—Black silk suture, 15 days. Minor degree of fibrous and cellular reaction around stitch.

70 days after operation, leaving fibrous scars behind.

Black unwaxed silk (*see Table I*) also sets up both fibrous and cellular reaction, which was found on the average even more marked than that after suture with white silk. *Fig.* 400 demonstrates a minor degree of reaction around the stitches 15 days after a black silk suture in *Case* 78*a*. As described in sutures with white silk, there was also in black silk sutures (*Cases* 96*b*, 110*c*) 17 and 25 days after junction a reaction of giant cells around the stitches.

Both fibrous and cellular reactions were found even stronger in those cases in which waxed black silk was used, as demonstrated in *Table I*. *Fig.* 401 shows the very marked fibrous reaction around the stitch in *Case* 517*a*, 19 days after anæsthesia (Young and Medawar, 1940). No large differences were found, fibres had grown nearly equally far after the use of all the suture materials mentioned above. This is the result which would be expected since the test shows

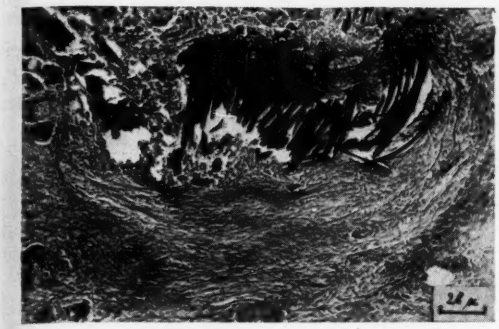

FIG. 401.—Black waxed silk suture, 19 days. Very marked fibrous reaction around the stitch forming an almost complete block for the outgrowing fibres.

FIG. 402.—Green silk suture, 15 days. Most extensive cellular reaction.

junction, forming an almost complete block for the outgrowing fibres. The great obstacle which the suture formed for the axons in this case was demonstrated by a number of Perroncito's spirals at the central border of the suture.

Green silk (*see Table I*) shows yet stronger fibrous and cellular reaction. The latter was particularly extensive in two of the three cases, as shown in *Fig.* 402, after the insertion of the stitch in a *suture à distance*.

Hair (*see Table I*) sets up both fibrous and cellular reaction, but the cellular reaction was the smallest seen with any of the materials used. The hair is apparently slowly attacked by giant cells. This was seen in *Case* 156*c* 52 days after operation, in which the nerve was crushed before cutting. The fibrous reaction, which on the average was found more definite than the cellular reaction, was, however, also slight. This is seen not only in an epineural suture (*Fig.* 403), but also in through-and-through sutures 25 days after a sharp division, as shown in *Fig.* 404. Even in a case after crushing before cutting the fibrous reaction was found remarkably small 52 days after operation (*Figs.* 405, 406). In all these cases at biopsy the neuroma formation at the point of suture was found the smallest compared with that of all the other materials. In some cases, however, the fibrous reaction was more pronounced around the stitches and spread away to a certain distance (*Cases* 185*c* and 321 in *Table I*). A striking feature brought out by the use of woman's hair for suture of so small a nerve as the rabbit's tibial was that the junction of the stumps was generally found more satisfactory than that obtained by other kinds of material. This was due to the great ease with which the sutures were inserted because of the small size and smooth surface of the hair.

In each of the above experiments an estimate was made of the distance to which fibres had reached by pinching the distal stumps under light the distance to which a few fibres have reached and differences would only appear if the barrier at the suture line was severe.

DISCUSSION

Although every suture material elicits both cellular and fibrous reactions, there cannot be any doubt that catgut sets up the greatest amount of cellular reaction. This demonstrates the definitely more irritative character of catgut as material for nerve suture. The reaction being not only localized around the catgut, which was itself found swollen, but spreading away from it to a considerable distance, is an undesirable hindrance for the passing fibres. The pinching reflex showed that the outgrowing fibres crossed the obstacle caused by the catgut reaction definitely not more readily than they did that after any other suture material. Moreover, in this connexion it may be emphasized that in man no reliable proof has ever been shown that nerve sutures with catgut give better functional end-results than those, for instance, with silk. Catgut can, therefore, by no means be considered as the " best suitable " material for nerve sutures. On the contrary, the fact that even to-day the question of sterility of catgut is still unsettled, ought to be a strong argument against its use as material for nerve sutures at all. As O. R. Clock's extensive bacteriological examinations of brands of catgut made in various countries have shown conclusively (1934, 1935, 1937), the danger of non-sterile catgut still exists.

The results obtained with silk material show that black and green silk elicits even greater reaction in transfixing suture than plain white silk. Black waxed silk can set up a particularly strong fibrous reaction. Although the insertion of the suture is facilitated by waxed silk, another disadvantage of this material may be considered: When the waxing of the silk is not done extremely thoroughly the wax may crumble away when

passing the stitch through the nerve, thus augmenting the foreign bodies and consequently the obstacles for the regenerating fibres within the nerve.

Woman's hair, being the finest of the suture materials, allows the smallest and neatest stitching with the least damage of fasciculi. Owing to its smooth surface it offers the advantage of waxed silk in facilitating the passing of the stitch through the nerve without having the above-mentioned disadvantage of waxed silk. These qualities make the hair suitable for epineural sutures even in nerves of small calibre or in cable grafts. When used as a transfixing suture the hair, however, has a distinct tendency, though on the average less than silk material, to elicit fibrous reaction close to, and to some extent spreading away from, the stitch.

All these findings show that whatever material is used for through-and-through sutures it sets up more or less undesirable reactions. These reactions undoubtedly augment the obstacles for the outgrowing fibres formed by the scar at the point of junction, or by intrafascicular scars below and above the junction, such as occur in cases in which the division of the nerve is associated with crushing, squeezing, or tearing.

The method of nerve choice for junction is an epineural suture, and transfixing sutures should be avoided whenever possible. This *can* be done in man in the great majority of cases. If in a special case a transfixing suture cannot be dispensed with, it should be carried out with the least irritating material, i.e., plain white silk, or, especially in nerves of small calibre, with woman's hair.

No special experiments were made to determine the tensile strength of hair sutures. It may be noted, however, that in all our cases of suture of the tibial nerve in rabbits a single hair suture was found sufficient to maintain a satisfactory position, although no form of immobilization was used in the post-operative period. In humans

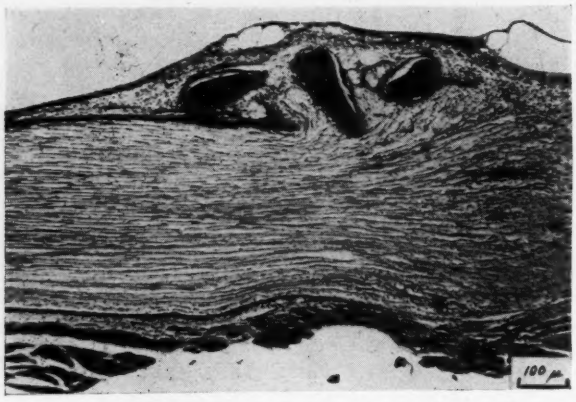

FIG. 403.—Hair suture, 7 days. Epineural suture showing very slight reaction around the stitch.

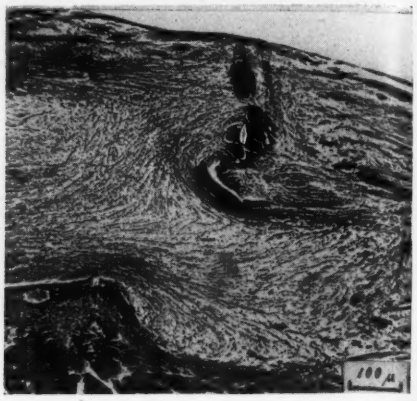

FIG. 404.—Hair suture, 25 days. Slight fibrous reaction around stitch spreading away for some distance.

FIGS. 405, 406.—Hair suture, 52 days. Suture after crushing the nerve before cutting. Only slight fibrous and cellular reaction around stitch.

some form of plaster splint is usually applied for at least 8 to 14 days. Therefore, these sutures will keep even larger nerves in apposition, particularly where little traction is required to bring the stumps together.

SUMMARY

In 24 rabbits plain sterilized catgut, plain white silk, green silk, waxed and unwaxed black silk, and woman's hair were used as suture materials for nerve sutures.

Whatever material was employed as through-and-through suture it always elicited undesirable cellular and fibrous reactions and obstacles for the regenerating axons. Woman's hair and plain white silk of finest size were found to be the least irritating materials. Of these two materials woman's hair, owing to its particularly small size and smooth surface, facilitates the passing of the stitch through the nerve, and allows the neatest stitching with the least damage of fasciculi in through-and-through sutures.

Both plain catgut and silk material impregnated with chemicals, the latter even when waxed, were found definitely inferior to plain white silk and particularly woman's hair.

The experiments confirm that through-and through sutures should be avoided whenever possible; the method of choice is the epineural suture.

I wish to thank Mr. J. Z. Young for his helpful advice and criticism. I also wish gratefully to acknowledge grants by the Nuffield Committee for the Advancement of Medicine and by Balliol College, Oxford, and the help of the Rockefeller Foundation for the expenses of this investigation.

REFERENCES

BABCOCK, W. W., *Surg. Gynecol. and Obst.*, 1927, **45**, 364.
BALLANCE, C., COLLEDGE, L., BAILEY, L., *Brit. Jour. Surg.*, 1926, **13**, 533.
FOERSTER, O., *Die Therapie d. Schussverletzungen d. peripheren Nerven*, 1929, 1604. Berlin.
CLOCK, O. R., *Surg. Gynecol. and Obst.*, 1934, **59**, 899.
CLOCK, O. R., *Ibid.*, 1935, **60**, 202.
CLOCK, O. R., *Ibid.*, 1937, **64**, 1027.
HANDFIELD-JONES, R. M., and PORRITT, A. E., *The Essentials of Modern Surgery*, 1938, 829. Edinburgh.
HUBER, C. G., *Amer. Jour. Morphol.*, 1895, **11**, 629.
HUBER, C. G., *Amer. Arch. Neurol.*, 1919, **2**, 466.
JEFFERSON, G., *A System of Surgery* (Choyce, C. C.), 1932, 289. London.
KENNEDY, R., *Brit. Jour. Surg.*, 1918–19, **6**, 322.
MAINGOT, R., *Post-Graduate Surgery*, 1936, 3445. London.
MEDICAL RESEARCH COUNCIL, *The Diagnosis and Treatment of Peripheral Injuries*, 1920–2, 1–59. London.
PLATT, H., *Modern Operative Surgery* (Turner, G. G.), 1934 **1**, 346. London.
ROMANIS, W. H. C., and MITCHINER, P. H., *The Science and Practice of Surgery*, 1937, 341. London.
SARGENT, P., and GREENFIELD, J. G., *Brit. Med. Jour.*, 1919, **2**, 407.
SOUTTAR, H. S., *Surgery of Modern Warfare* (H. Bailey), 1941, pt. iii, 351. Edinburgh.
STILES, H. J., and FORRESTER-BROWN, M. F., *Treatment of Injuries of the Peripheral Spinal Nerves*, 1922, 56. London.
THOREK, M., *Modern Surgical Technique*, 1938, **2**, 533. London.
YOUNG, J. Z., and MEDAWAR, P. B., *Lancet*, 1940, **2**, 126.

SHORT NOTES OF RARE OR OBSCURE CASES

A CASE OF PARATHYROID ADENOMA

By IAN M. ORR

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A REVIEW of the published cases of parathyroid adenoma shows how widely the symptomatology may vary from case to case and how seldom one finds all the classical features in one example. The case recorded below exhibited so many features of this complicated condition that it is worth putting on record.

CASE REPORT

HISTORY.—A young woman aged 35, an elocution teacher by profession, presented the following history: She had lived in South Africa during her early life and was treated for rheumatism when 6 years old. She had diphtheria at the age of 10, and her adenoids and tonsils were removed some years later. She always tended to suffer from indigestion and nausea, and in 1933 a barium meal showed considerable irritability of the duodenal cap, suggestive of duodenal ulcer. Medical treatment was successful in curing this complaint. In 1935 she had pleural effusion following influenza, but this cleared up completely, and radiographs of the lung failed to show any underlying cause. Her menstrual periods were irregular. In 1936 renal symptoms manifested themselves in polydipsia and polyuria, and these have been more marked during the past year. By nature she was always a restless person, and during 1940 this restlessness increased, especially at night. During the past two years she has experienced loss of muscular power and has complained of rheumatic pains in the legs. In September, 1940, she fell while walking and hurt her right hip. The pain in the hip and pelvis persisted, and became worse if both legs were abducted, and the pain was eased if both thighs were slightly flexed and externally rotated. The gait therefore became abnormal. She twisted her ankle in October with agonizing pain, and in December fell off her bicycle with exacerbation of her hip and pelvic pain. Her weight decreased by a stone in six months.

December, 1940, her general condition deteriorated rapidly, she became unable to walk, and complained of continual pain in the pelvis and limbs. She was listless and apathetic, and suffered greatly from nausea and vomiting, with the result that she began to lose weight rapidly. A radiograph showed fracture of the right and left pelvic rami. That on the right

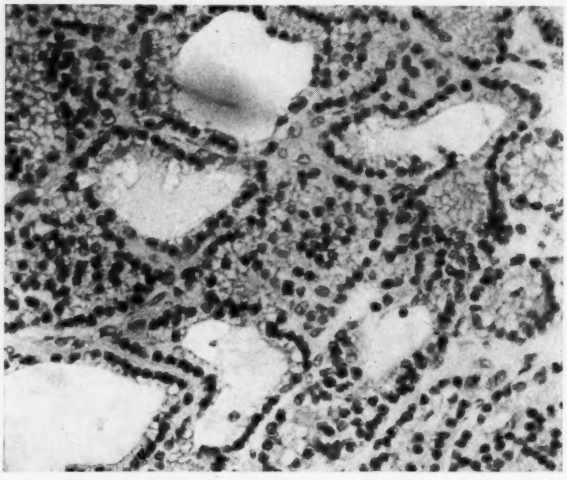

FIG. 407.—Parathyroid adenoma. Columnar-celled alveoli, lined with water-clear cells. (H. and E.) (× 220.)

side appeared recent, but the bone on the left side was so abnormal that no estimate of the age of the fracture could be made. All the bones of the pelvis showed fibrocystic changes, and the right femur appeared to contain a cyst in the upper part of the shaft. On Dec. 31 the blood-calcium was 19 mg. per cent, the blood-phosphate 1·88 mg. per cent, hæmoglobin 85 per cent, R.B.C. 4,620,000, and the C.I. 0·92.

ON EXAMINATION (Dec. 24, 1940).—

The thyroid gland was not enlarged, though there was a small thickening the size of a pea on the right side of the neck under the lower end of the sterno-mastoid muscle. No lump was palpated on the left side.

Skeleton: There was marked tenderness over the coccyx and right pelvic ramus. The right tibia and fibula were tender, but not enlarged or irregular. There was no outward evidence of fracture such as ecchymosis or swelling. The ribs were tender, but the spine moved frely.

Chest: Considerable diminution of movement on the left side and diminished percussion note at the left base. No adventitious sounds. Clubbing of finger-nails and toe-nails present.

Circulation: Heart normal. Pulse 68, regular. B.P. 130/80.

C.N.S: Cranial nerves normal, but right pupil larger than left. No nystagmus; some ptosis of the right eyelid. Arms normal in tone and power. Jerks depressed. Leg tone normal, but loss of power of flexion of right leg. Knee- and ankle-jerks normal. Co-ordination of arms and legs normal; dysdiadokokynesis absent.

Urine: Normal, but polyuria and polydipsia.

Abdomen: Not tender. No mass palpated. No enlargement of liver or spleen.

X-ray Examination of Skeleton.—

Skull: Presented an extremely mottled appearance, the entire vault being affected with patchy rarefaction of upper parietal region.

Thorax: Both clavicles showed rarefaction at their medial extremities. The ribs showed fibrocystic changes similar to those already described in the pelvis. A soft tissue shadow was seen in the *left* side of the neck.

Long bones: Cystic patches and decalcification of the cortex, with some periosteal reaction, the latter being particularly marked in both femora and the right tibia and fibula.

AT OPERATION (Dec. 31, 1940).—Under avertin and gas and oxygen anæsthesia a transverse incision was made and the fascia and pretracheal muscles separated in the midline, and the lobes of the thyroid elevated. Behind the left lobe a firm movable swelling enveloped in fascia was palpated. It could be moved freely up and down and was about the size of a hazle-nut. The fascia covering it was incised and the tumour dissected out without difficulty. There was a vascular pedicle. A search was made in the retrosternal space, but no other mass was detected on this side. On the opposite side a small normal parathyroid gland was seen, but no tumour could be detected in relation to the right lobe, and the incision was closed.

POST-OPERATIVE COURSE.—The immediate post-operative condition was excellent. There was no shock. The temperature rose to 100° during the first forty-eight hours, but by the fourth day the pulse and temperature were normal. The patient complained of severe tingling in the hands and feet, and there was well-marked tetany. Calcium gluconate, 10-c.c. solution, was injected intravenously every four hours during the first two days. Thereafter calcium lactate, 30 gr., with parathyroid extract, was given by the mouth four-hourly for a week and less frequently during the following week. Hydrochloric acid, 30 min., was given thrice daily with meals, and glucose drinks were freely administered. After the first post-

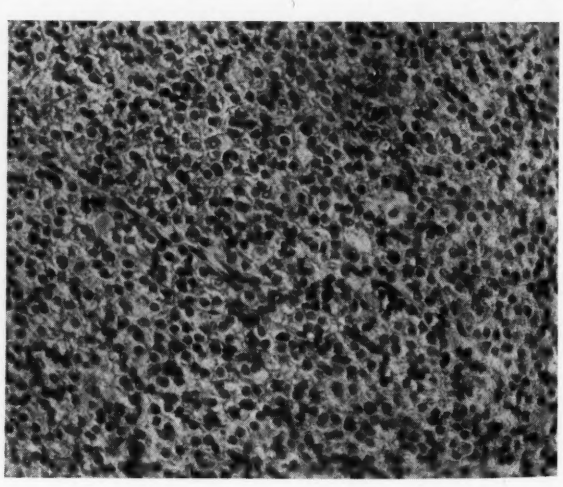

FIG. 408.—Parathyroid adenoma. Solid area. Transitional cells (i.e., transition from 'dark principal' to 'water-clear principal' cells). (H. and E.) (× 220.)

operative day, vomiting ceased and she was able to enjoy food, a thing she had not done for months. She expressed herself as feeling much better but for the tingling, which was quite severe before the next injection was due. On Jan. 2, two days after the operation, the blood-calcium was 9·2 mg. per cent and the serum-phosphates 1·5 mg. per cent. A week later the readings were 7·7 mg. and 3·4 mg. per cent

respectively. Six weeks later the serum-calcium was 8·6 mg. per cent, and three months after the operation it was 9 mg. per cent.

PATHOLOGICAL REPORT ON TUMOUR.—"The tumour looks like an enlarged lymph-gland and measures 3 cm. × 2 cm. × 1 cm., and weighs 4 g. It had a thick capsule which strips easily, and, on section, shows a cortical zone of round yellow nodes and a medulla composed of two larger nodes, one hæmorrhagic and the other of broken-down caseo-calcareous material. Section of the cortical part shows an adenoma of the parathyroid. The cell type is uniform and arranged in solid blocks or more rarely in acini and columns. In these places the individual cell is cuboidal and has a basal nucleus and reticulated cytoplasm." (*Fig.* 407, 408.)

LATER PROGRESS.—The patient was able to do without calcium by the mouth after six weeks. All gastro-intestinal and urinary symptoms rapidly cleared up, but walking was long delayed and the gait was unsteady and uncoordinated with dragging of the feet for four months following the operation. Speech was somewhat slurred during the early weeks, and the patient found difficulty in making the facial and lip movements necessary to form certain sounds, no doubt due to the tendency to tetany. Her walking and general health gradually improved, and one year after her discharge from hospital she reported that she was extremely well. She has put on weight and walks normally and is now back at work as a teacher of elocution. Radiography shows considerable increase in the calcium content of the bones. The cystic areas in the pelvis have practically disappeared and the pelvic rami appear normal, though the old fracture on the right ischium can just be seen. The radius, ulna, tibia, fibula, and femur of the right and left sides are normal in appearance. All the cystic areas have disappeared.

Eighteen months after the operation she reported that she was very well in her general health, but suffered from heartburn. A test-meal examination showed a marked deficiency of free hydrochloric acid.

CONGENITAL DISLOCATION OF THE HEAD OF THE RADIUS

BY JAMES R. A. WHITE

TEMPORARY SURGEON, DUDLEY ROAD HOSPITAL, BIRMINGHAM

CONGENITAL dislocation of the head of the radius without associated synostosis of the radius and ulna is very rare. British literature was devoid of such accounts until McFarland described the condition in detail. He described several cases, and these equal the number recorded by other authors. The universal use of radiological investigation of injuries has not increased the number of cases recorded to any marked extent. The condition should be suspected in all cases of anterior dislocation of the radius without fracture of the ulna. Failure to recognize the condition will result in repeated manipulations, which cannot achieve a satisfactory result.

CASE REPORT

A. W., female, aged 50 years, attended the hospital complaining of pain in the right elbow following a fall.

ON EXAMINATION.—There was some bruising over the olecranon and a palpable mass in the cubital fossa which moved with the radius. Comparison with the left elbow showed that the circumference of the elbow was greater on the right side (*Fig.* 409). On the right side flexion was limited both actively and passively to 70°. Extension and rotation were full. No previous accident to the elbow had occurred. At all times she had been able to perform her considerable household duties without pain.

Radiological examination (*Fig.* 410, A, B) revealed an anterior dislocation of the head of the radius. There was no fracture of the ulna. Comparison with plates taken of the left elbow and forearm showed that this dislocation agreed with the description given by McFarland. On the right side the radius was longer. The head, dome-shaped, had no depression for articulation with the capitulum of the humerus. An area of dense calcification lay over the head and appeared to be attached anteriorly. The alteration in the normal anterior curve of the posterior surface of the ulna showed that the ulna had not been unaffected by the dislocation.

Further examination was made with the help of the fluorescent screen. Flexion of the elbow showed the head of the radius sliding over the anterior surface of the humerus until flexion was inhibited by the pressure of the humerus on the sesamoid lying over the head of the radius. In full extension the head of the radius lay dislocated over the anterior surface of the capitulum. During rotation a gap was constantly visible between the coronoid and head of the radius.

FIG. 409.—Photograph comparing right and left elbow regions.

TREATMENT.—This consisted in resting the arm for one week. Although at the end of that time the range of movement was as previously described, the patient declared that her arm was normal and was discharged.

REVIEW OF CASES

Bonneberg, 1893, in Germany, and Blodgett, 1906, in America, have reviewed the literature on congenital dislocation of the elbow. In these reviews they do not discriminate between cases such as described above, and cases which are complicated with multiple deformities, or cases in which the dislocation is partly the result of the

fusion of the bones of the elbow. The cases listed below are all examples of anterior dislocation not associated with other congenital lesions.

1. *Mitscherlich.*—
Female, aged 6. Bilateral dislocation of the head of the radius. On examination, the flexion of the right elbow was 70°, of the left elbow 100°. There was full extension, but limited rotation. Langenbeck resected the left elbow-joint, but the child did not recover from the operation. This afforded an opportunity for a complete dissection of the right elbow region. The findings were :—

a. The head of the radius was higher than usual and the distal surface was conical instead of concave.

b. A groove was present on the anterior surface of the humerus with a proximal fossa, covered with articular cartilage, with which the head of the radius articulated.

c. There was no joint between the head of the radius and the coronoid.

d. A ligament passed from the coronoid to the shaft of the humerus. A ligament which performed the functions of the annular ligament was attached to the lateral condyle of the humerus. The collateral ligaments were normally placed.

2. *Leisrink.*—
Male, aged 18. Left anterior dislocation. This patient came under observation when he dislocated his elbow. The ulna was reduced under general anæsthesia, but the radius could not be reduced. It was then discovered that the deformity of his left elbow had been noticed when he was 3 years of age, and had been ascribed to the violent measures employed to resuscitate him at birth. His movements were almost full, so no other treatment was required.

3. *Mauchenhauer.*—
Male, aged 12. This was an accidental finding when the boy was being examined. The head of the radius was easily palpable. Flexion and extension were both slightly limited.

A B

FIG. 410.—Radiographs of right elbow, showing rounded head of radius and sesamoid type of hypercalcification. A, Lateral ; B, Antero-posterior.

4. *Joppich.*—
Male, aged 15. Left anterior dislocation. Again an accidental finding. Movements were full except flexion, which was limited to 80°.

5. *Bonneberg.*—
Female, aged 20. Right anterior dislocation. On examination the head of the radius was easily palpable. Passive flexion and extension were slightly limited, but the forearm was fixed in supination. He performed several operations for the alleviation of the condition : (*a*) The head of the radius was excised. The head of the bone was infantile and had no hollow. Posteriorly only was there articular cartilage, and this articulated with a continuation of the cartilage of the capitulum which lay on the anterior surface of the humerus. (*b*) As this did not provide free rotation he performed an osteotomy on the lower third of the radius, and removed the distal 3·5 cm. of the ulna. The wounds healed by granulation, and three months later she had full passive movement. Voluntary rotation was still absent.

6. *Powers.*—
Male, aged 13. This patient had a deformity since birth. On examination the radius was elongated, and the head palpable in the cubital fossa. Flexion was to 90°, with full extension. The forearm was fixed in pronation. Powers wished to excise the head of the radius, but as he was unable to guarantee a complete cure, operation was refused.

7. *La Ferté, quoted by Blodgett.*—
Male, aged 6. There was anterior dislocation of the head of the radius. The forearm was fixed in extension and pronation. Radiographic evidence proved that no fusion existed between the bones. Treatment consisted in excision of the head of the radius. Later examination showed that the patient had flexion to 90° and slight rotation, although there was partial regeneration of the head of the radius.

8–18. *McFarland.*—
Eleven cases in children are cited. The following points given by McFarland have been fulfilled in the cases selected for review :—

a. There is no fusion of the bones.

b. The radius is longer than normal.

c. The head of the radius is malformed, being small and elongated. There is a rudimentary depression proximally instead of the broad shallow depression for the capitulum. Occasionally there is an area of ossification overlying the head of the radius comparable with the occasional sesamoid type of calcification which may occur over the head of a congenitally dislocated femur.

d. The proximal end of the ulna shows an anterior curve over the olecranon, and a straight line instead of a backward curve from the coronoid.

He has noted a case when, in conjunction with a fracture of the ulna, the general appearance simulates a Monteggia fracture. Excision of the head of the radius gave good results in cases requiring operative interference.

19. *Rose.*—
Male, aged 13. This patient fell and injured his elbow three days prior to admission to hospital. The condition was recognized as a congenital dislocation after repeated attempts at reduction had failed. The limitation of movement was relieved by complete rest in a collar-and-cuff sling.

20. *Mauch and Butterworth.*—
Male, aged 15. Bilateral. This patient could do work, but complained of a " click " on full extension. Radiography showed that the head of the radius was dislocated, but was reduced on full extension. Excision of the head of the radius relieved his symptoms.

21. *Meng.*—
Male, aged 18. Bilateral. Both elbows had 60° of movement, but were fixed in the semi-prone position. Operation was refused. Meng notes that in addition to the findings of McFarland, his case showed an absence of the styloid process of the radius and ulna.

22. *Author's case.*—
It will be noted that all, with the exception of the last case, occurred in patients under 20 years. Most of the cases were accidental findings when other injuries in the neighbourhood of the elbow were examined. The fact that congenital dislocation of the elbow is a definite entity is of medico-legal importance when other injuries occur in the neighbourhood of an elbow so constituted.

AETIOLOGY

Much has been written in the early literature on the causes of congenital dislocation of the elbow. These can be summarized under the two heads of intra-uterine trauma and of defective joint construction. In none of the reported cases was an abnormality found at birth, and I feel that the case of Leisrink gives a clue to the possible explanation of the condition. In his case a definite history of violent resuscitation from birth asphyxia was obtained. Every hospital has many cases of ' pulled elbow ' in children of the age group 2–5. The child is walking along a road, and, while firmly held by the hand, falls ; then he is jerked forcibly to the upright position, and later, when examination is made, it is found that the elbow is extended and that voluntary flexion is not possible. If the arm is passively flexed and rotated, a hand placed over the elbow region will feel a click, which suggests that a subluxation of the head of the radius has been reduced. The child immediately regains full active movement. A period of rest in a sling allows the ligaments to return to normal. In a certain number which may be reduced at home no rest will be given. Thus in a small number of these cases a permanent laxness of the ligament results in a recurring or permanent dislocation of the head of the radius, which maintains its infantile or conical appearance.

TREATMENT

In those cases which are discovered accidentally, and in which no marked disability is present, no treatment is indicated. In the cases in which there is a disability, satisfactory results are achieved by excision of the head of the radius.

SUMMARY

1. A case of congenital dislocation of the head of the radius is described.
2. The literature is summarized.
3. The aetiology is considered.

I wish to thank Dr. T. M. Anderson, Medical Superintendent, for permission to publish this case, and Mr. Russell Green for radiological help and advice.

REFERENCES

BLODGETT, WM. E., *Amer. Jour. Orthop. Surg.*, 1905–6, 253.
BONNEBERG, *Zeits. f. Orthop. Chir.*, 1892–3, **2**, 376.
JOPPICH, quoted in detail by BONNEBERG.
LEISLINK, quoted in detail by BONNEBERG.
MCFARLAND, B., *Brit. Jour. Surg.*, 1936, **24**, 41.
MAUCH, H. PAGE, and BUTTERWORTH, R. D., *Jour. Amer. Med. Assoc.*, 1938, **114**, 2542.
MAUCHENHAUER, quoted in detail by BONNEBERG.
MENG, C. M., *Chinese Med. Jour.*, 1940, **57**, 479.
MITSCHERLICH, quoted in detail by BONNEBERG.
POWERS, C. A., *Jour. Amer. Med. Assoc.*, 1903, **2**, 165.
ROSE, THOMAS, *Med. Jour. of Australia*, 1938, **1**, 741.

DISLOCATION OF THE CARPAL SCAPHOID REDUCED BY OPEN OPERATION

By G. B. WOODD WALKER

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DISLOCATION of the carpal scaphoid is a rare injury. The case here described is the only one I have seen; the condition is not described in the standard books.

CASE REPORT

HISTORY.—A. W., male, aged 44, laundry carman. On Aug. 18, 1941, when hand-cranking his van, the engine back-fired. Being well acquainted with the vices of the engine his thumb was round the handle alongside the index. He felt a severe jar up his arm, and his right wrist was immediately noticed to be swollen. His mate "pulled his hand" for him, and the pain became easier. He noticed an unusual prominent bone at the base of the thumb. He consulted Dr. Mann, of Staines, who referred him to Staines County Hospital.

ON EXAMINATION.—When I examined him on Aug. 22, there was much swelling of the back of the hand and wrist, and movement was limited to 30° flexion-extension. A bony prominence immediately distal to the radial styloid was palpated. Fracture of the scaphoid, with wide separation of the fragments, was thought to be the result of the injury.

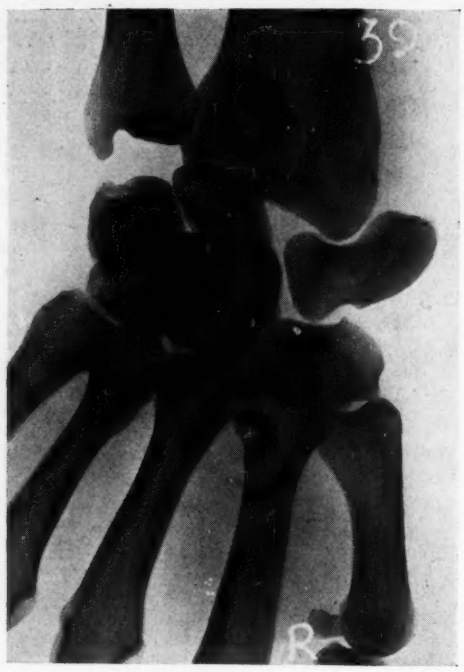

FIG. 411.—Radiograph showing the scaphoid dislocated and gripped between the radial styloid and os multangulum majus.

X-ray examination, however (*Fig.* 411), showed a dislocation of the scaphoid; the bone was rotated through 180° in the coronal plane, so that its upper and inner angle was subcutaneous, the waist of the bone being nipped between the radial styloid and the greater multangular bone. The only evidence of associated injury to be noticed was a slight periosteal disturbance on the dorsal surface of the os magnum.

The œdema had considerably subsided in five days; an attempt at reduction by manipulation had failed; open operation was therefore undertaken.

AT OPERATION.—Under a tourniquet a 3-in. incision was made on the radial side of the carpus, and the tendons of extensor pollicis brevis and abductor pollicis were retracted anteriorly. Even then reduction of the displaced scaphoid proved unexpectedly difficult, chiefly owing to the tenseness of the remaining capsular attachments, and the necessity of avoiding damage to the cartilage-covered facets in controlling the bone. Finally, the bone was separated from all its attachments and laid aside in a bowl of saline. After the torn edges of the capsule had been trimmed, the hand was held in full ulnar deviation and the bone inserted head first into its bed. It fitted snugly and seemed so much at home that no retention by suture was necessary. Sulphonamide powder was insufflated, the wound closed, and the wrist put up in plaster in the mid-position. The plaster was renewed when the wound had healed in a week and maintained for six weeks. Radiographs showed the scaphoid to be normal in density and position, and apparently none the worse for its outing (*Fig.* 412).

FIG. 412.—Radiograph taken at operation showing the scaphoid replaced after removal. A, Antero-posterior view; B, Lateral view.

PROGRESS.—On removal of the plaster full and painless function quickly returned and he was able to do heavy work in handling laundry baskets. Radiographs taken at this time, however (*Fig.* 413), clearly show decalcification of the wrist and hand, but, as Watson-Jones has emphasized, this cannot affect the calcification of the bone which has been isolated, so that the scaphoid stands out as the densest bone in the carpus. As recalcification of the wrist proceeds, this difference becomes less and less marked (*Fig.* 414).

Watch will continue to be kept on this wrist at two-monthly intervals for degenerative arthritic

changes, though I think that such changes are not likely to occur when revascularization has proceeded so smoothly and completely.

All movements at the wrist are now full and painless; extension only is limited by 5°. There is no tenderness on pressure over the bone.

FIG. 413.—Radiograph taken 7 weeks after operation, showing decalcification of the wrist. The formerly dislocated scaphoid is not affected by this process. The relative increase in density is apparent only.

COMMENT

The rarity of dislocation of the scaphoid compared with the semilunar is surprising. The 'squeezing-out' force held responsible for dislocation of the semilunar might well be applied to the scaphoid when the force is transmitted through the radial side of the hand. Then, however, the scaphoid is gripped between the lower end of the radius and the multangular bones, and fracture of the lower end of the radius or of the waist of the scaphoid results.

In the case reported above the mechanism may have been somewhat different, as the exact

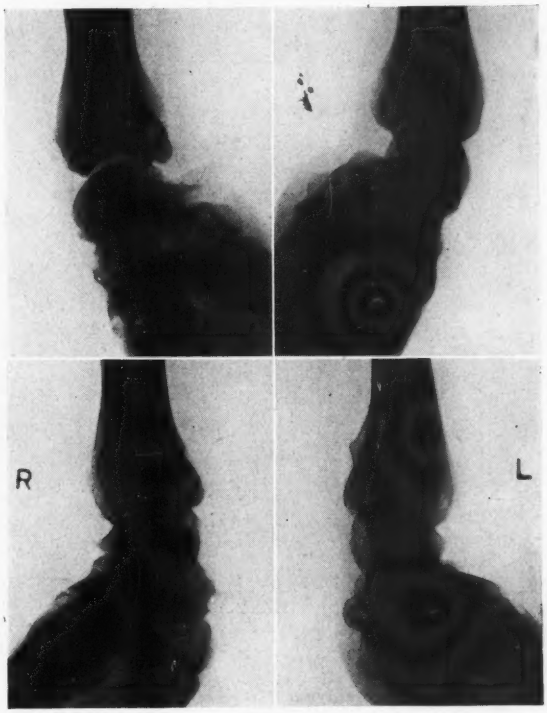

FIG. 414.—Radiograph taken 7 months after operation, showing the range of movement and the calcification of the bones of the injured and uninjured wrists to be normal.

sequence of events in the production of the dislocation is not clear. It is possible that the backfire produced a complete dislocation backwards of the carpus at the radio-carpal joint, and that this, excepting the scaphoid, was instantly reduced by his ready mate. Close-questioning cannot further elucidate exactly what this early manipulation succeeded in achieving. It remains a puzzle to understand how the head (the upper and inner part) of the scaphoid escaped without an associated fracture of the radial styloid.

A MIXED TUMOUR OF THE KIDNEY IN AN ADULT

By THOMAS MOORE

FROM THE UROLOGICAL SERVICE OF THE MANCHESTER ROYAL INFIRMARY

WILMS, by his description in 1899, clearly distinguished a type of kidney tumour which was characterized by its extreme malignancy, its occurrence in children, usually under three and very rarely over ten years of age, and by its heterogenous histological structure, both epithelial and connective-tissue elements being present. Such a tumour has since been a distinct and recognized type, commonly known as Wilms' tumour. Other names also used are mixed tumour of the kidney, adenomyosarcoma, rhabdomyosarcoma, embryoma, and dysembryoma—all

terms which describe some actual or theoretical feature of the tumour. Occasionally such cases have occurred in adults. A study of the literature has shown that to date 26 cases of the disease in adults have been reported. In them, as in children, the tumour is very malignant, and cure is almost

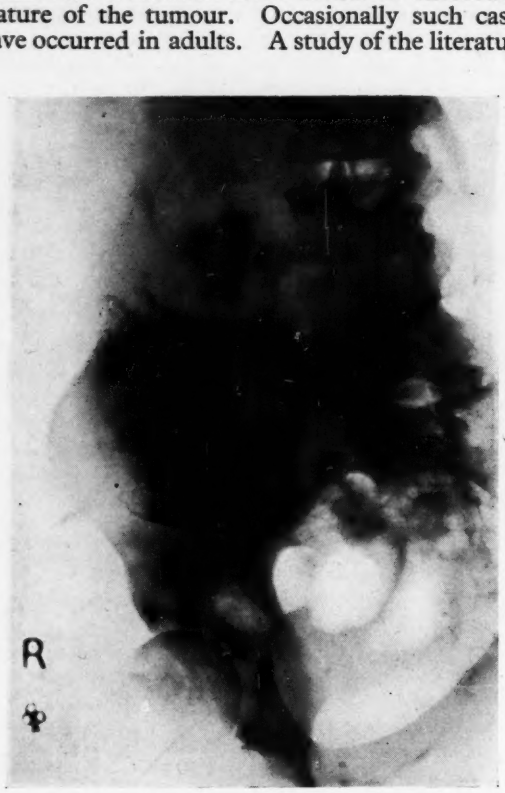

FIG. 415.—Plain radiograph showing diffuse calcification of the lower part of the tumour.

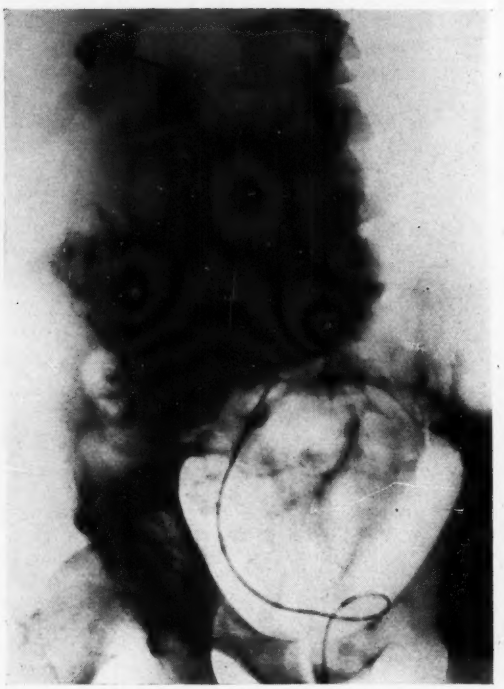

FIG. 417.—Retrograde pyelogram showing the marked displacement of the ureter.

FIG. 416.—Excretion urogram showing the upper part of the kidney pelvis and the upper calices outlined.

unknown. The only cases which have survived for any length of time after operation which I have been able to find recorded in the literature are those reported by Hunt and Hager (1929) and Priestly and Broders (1935).

The tumour is most probably of developmental origin. Wilms suggested, because of the muscle content, that the tumour arose from part of a myotome which had become included in the developing kidney. It is well to recognize, however, that all kidney structures, epithelial or otherwise, are of mesodermal origin and that there is no endo- or ecto-dermal tissue in the kidney. All the elements of a Wilms' tumour could arise from normal kidney tissues. A most interesting point of view along these lines has been advanced by Geschickter and Widenhorn (1934) to explain the origin of all kidney tumours. Wilms' tumour is probably derived from some primitive mesenchymal multipotent kidney cells which become isolated and imprisoned in part of the developed organ, and later, in response to some unknown stimulus, begin to grow and give rise to all the varied tissues which may occur in the neoplasm.

Like all other types of teratomatous deposits, the malignancy varies from case to case. Although in adults the tumour is the most malignant encountered, many authors have pointed out that

it is not quite so malignant as its counterpart in children. I wish to report a case here of mixed tumour of the kidney, which by its long period of growth would appear at first sight to be far removed from Wilms' tumour, but which in effect belongs to the same histiogenic group.

CASE REPORT

HISTORY.—A male patient, aged 56 years, was admitted to the Manchester Royal Infirmary on March 25, 1939. He stated that in 1914 he had sustained an injury to his right loin when several heavy boxes had fallen on to him. He was away from work for six months. There was no hæmaturia. After this he was quite well for two years. He then suffered from hæmaturia, associated with several attacks of right renal colic, for fourteen days. Since that time until admission he had had several similar attacks of hæmaturia and colic at intervals of from four months to one year. For ten years he had been conscious of a swelling in the right side of his abdomen, which during the last four months has become rapidly very much bigger. In December, 1938, he had developed marked swelling of the legs, which had lasted for about three weeks. For about three months before his admission he had complained of palpitation and shortness of breath, and for fourteen days hæmoptysis.

Previous History: He was an in-patient in another hospital in December, 1923. At that time he was found to have a large right renal tumour which, on X-ray examination, was seen to be partially calcified. It was diagnosed as a hypernephroma. Operation was advised but refused.

ON EXAMINATION.—The patient looked very ill and had obviously lost much weight. A marked degree of mitral stenosis was present. The whole of the right side of the abdomen was occupied by a large renal swelling, which was causing a marked protrusion of the abdominal wall. The surface of the swelling had irregular bosses on it. There was no movement of the tumour with respiration. The other systems were normal to clinical examination. The urine was macroscopically normal, but on microscopical examination was found to contain a few red blood-cells. It was sterile on culture. Plain X-ray examination (*Fig.* 415) showed marked enlargement of the right renal shadow and diffuse calcification in the lower part of the shadow An excretion urogram (*Fig.* 416) showed good function and normal outlines of the left kidney. The function of the right was much reduced. In the later films the outline of the upper two calices and part of the pelvis could be seen. The bladder and posterior urethra were seen to be normal on cystoscopy. A No. 5 F. ureteric catheter was passed easily up the right ureter to 30 cm. The retrograde pyelogram (*Fig.* 417) confirmed the findings of the excretion urogram, but showed in addition the very marked medial displacement of the ureter.

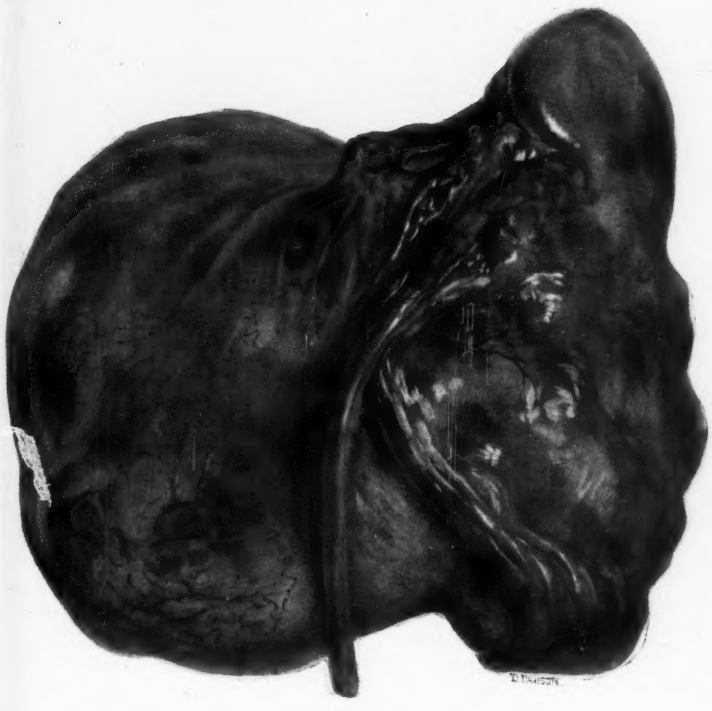

FIG. 418.—Drawing of tumour, showing that it had replaced all except the upper pole of the kidney.

FIG. 419.—A section through the kidney, showing variegated appearance of tumour.

The patient went steadily downhill. No further swelling of the legs or gross hæmaturia occurred, but slight hæmoptysis continued until death on June 9, 1939.

AT AUTOPSY.—The main autopsy findings were:—

1. A severe degree of mitral stenosis.
2. Embolism of the right branch of the pulmonary artery with infarction of the lower lobe of the right lung.

3. A large infarct in the upper lobe of the left lung.
4. Near the apex of the left lung there was a metastasis 1 cm. in diameter.
5. There were several small metastases in the liver.

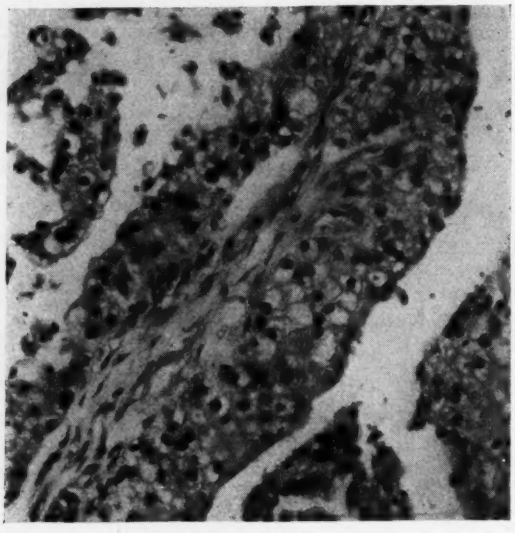

FIG. 420.—Photomicrograph showing hypernephroma-like cells. (× 150.)

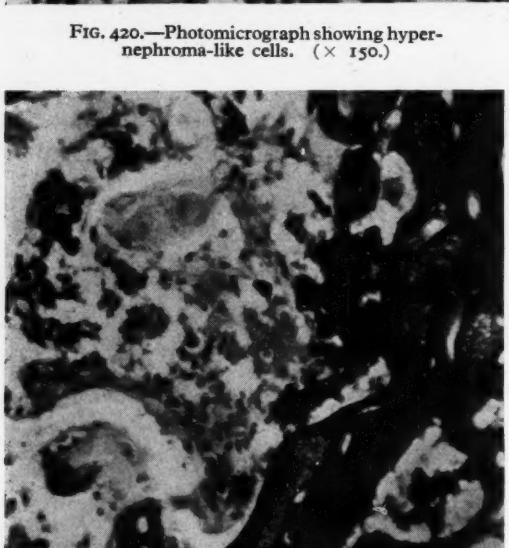

FIG. 421.—Photomicrograph showing ossification. (× 150.)

6. Both common iliac veins showed recent thrombosis.

7. Occupying the whole of the right side of the abdomen was a large renal tumour. It measured 17 cm. across its widest part and extended from the under surface of the liver, to which it was adherent, to the brim of the true pelvis. The tumour had entirely replaced the kidney except at the upper pole (*Fig.* 418). On section the tumour had a very variegated appearance (*Fig.* 419), but most of the tissue looked like myxoma. In it there were several small cysts containing yellow fluid. Near the centre there was a very hard area which had to be cut with a saw.

Histological examination showed many types of tissue. There were large areas composed of big vacuolated hypernephroma-like cells, in parts of which calcification had taken place, interspersed with

FIG. 422.—Photomicrograph showing sarcoma with giant cells. (× 150.)

areas of myxomatous, myosarcomatous, and sarcomatous tissues, the latter of which contained many giant cells. In other parts ossification had occurred (*Figs.* 420–422). In spite of special staining, no striped muscle could be demonstrated in the tumour. The metastases had a similar structure to the parent tumour but no calcification or ossification had occurred.

Discussion.—This case is certainly unique in the length of time (16 years) the tumour was definitely known to have been present. It probably arose from some primitive mesenchymal renal cells which had been sequestrated in the kidney during development. Possibly the trauma sustained two years before symptoms of the tumour were experienced was the stimulus which stirred these cells into activity.

I must thank Mr. H. H. Rayner, under whose care the patient was admitted to hospital, for permission to make this report. I am also indebted to Miss D. Davison and Mr. Taylor respectively, for the coloured drawings and the photomicrographs.

REFERENCES

GESCHICKTER, C. F., and WIDENHORN, H., *Amer. Jour. Cancer*, 1934, **22**, 620.
HUNT, V. C., and HAGER, B. H., *Surg. Clin. N. Amer.*, 1929, **9**, 149.
PRIESTLY, J. T., and BRODERS, A. C., *Jour. of Urol.*, 1935, **33**, 544.
WILMS, M., *Die Mischgeschwülste*. Hft. 1, "Die Mischgeschwülste der Niere", 1899. Leipzig.

SPIGELIAN HERNIA, WITH REPORT ON A CASE

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AND W. C. OSMAN HILL
PROFESSOR OF ANATOMY, CEYLON MEDICAL COLLEGE, COLOMBO

SPIGELIAN hernia is a rare form of ventral hernia occurring through the linea semilunaris (linea Spigelii) of the anterior abdominal wall. Various muscular defects of the anterior abdominal walls are listed and classified by Binder (1927) in Schwalbe's well-known treatise, but no defect of the linea semilunaris is therein referred to. Hernia through defects in this part of the parietes is evidently fairly frequent, however, if we are to accept the cases of so-called Spigelian hernia found in surgical literature, though it receives scant attention in standard surgical treatises.

Between 1927 and 1940 no less than twenty-three papers on the subject are listed in the *Index Medicus*. Most of them are in journals of Italian, Spanish, or French origin, and none has been accessible to us, but we append a list at the end of the present contribution partly for the sake of completeness and partly for the reference of those more favourably placed than ourselves in the matter of library facilities.

We describe below an example of Spigelian hernia that came under the care of one of us (M. P.) and was later investigated in detail anatomically, hoping that some points would be cleared up thereby.

CASE HISTORY

S. T., aged 10, female, was admitted on Sept. 10 on account of a large right-sided hernia through the abdominal wall. This hernia had been noted from birth, but had gradually increased in size. On examination there was seen a large swelling on the right side of the abdomen extending from the right loin posteriorly to the middle line in front, and from the costal margin above to the iliac crest below (*Fig.* 423). The swelling was covered with normal looking skin, but through the skin was seen the outline of coils of small intestine, which showed peristaltic movement. On palpation the coils of intestine were felt immediately under the skin, and there appeared to be a large gap bounded behind by the outer margin of the erector spinæ muscle, in front by the outer edge of the rectus muscle, above by the costal margin, and below by the iliac crest. The hernia was irreducible, and this irreducibility of the hernia did not fit with the conception that there was here so extensive a deficiency of the abdominal wall as appeared on palpation. It was, however, quite clear that there was a hernia through the abdominal wall.

OPERATION (Sept. 20).—A curved incision was made round the upper margin of the hernial swelling down along the outer border of the right rectus muscle. The hernial sac was closely apposed to the overlying skin and the skin incision opened into the hernial sac. The sac contained the small intestine, the right colon, which had a long loose mesentery, and the omentum. These viscera emerged through an oval hole in a septum extending from the rectus muscle in front to the erector spinæ muscle behind. The septum was thick, firm, and infiltrated with fat,

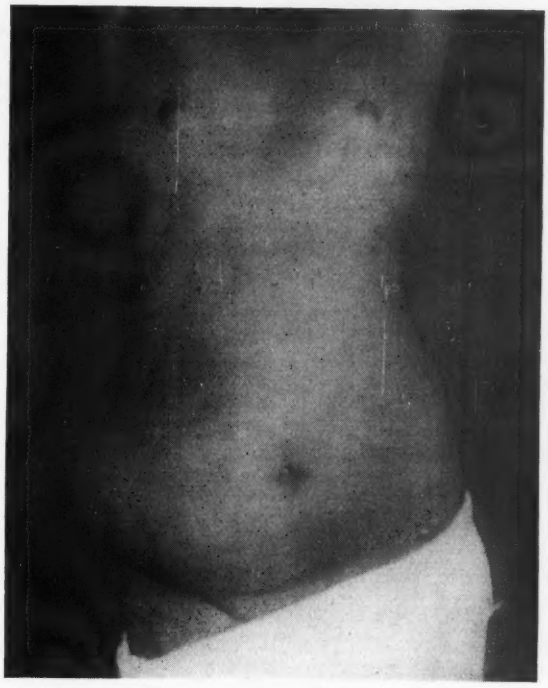

FIG. 423.—Photograph of the living patient exhibiting hernia through the linea semilunaris spigelii on the right side.

giving it a yellow colour. The hernial contents were reduced through the oval orifice into the abdominal cavity, and at this stage it was decided to repair the hernia by closing the oval orifice with sutures. This was accomplished by sutures of fine silk which secured apposition along a triradiate line. The excess of skin overlying the hernial sac was excised and the wound closed.

POST-OPERATIVE COURSE.—After the operation the patient complained of severe abdominal pain. She also began to vomit. The abdomen was soft and not distended. Permission to perform a second operation was refused, and the patient continued vomiting and her pulse steadily deteriorated. She remained in severe abdominal pain until her death two days after the operation.

POST-MORTEM OPERATION.—Permission was obtained to perform a partial post-mortem examination. The peritoneal cavity was opened in the middle line. The small intestines were greatly dilated up to within 2 ft. of the iliocæcal valve, where a knuckle of bowel, 2 in. long, was found strangulated in a cone-like

cavity which had been produced on the septal wall by suturing of the oval hole into a triradiate line, the cone being at the line of junction of the three lines. The peritoneal cavity was clean, the spleen and liver were normal, the stomach and small intestine had a normal disposition, but both ascending and descending colons were freely mobile, being suspended by long

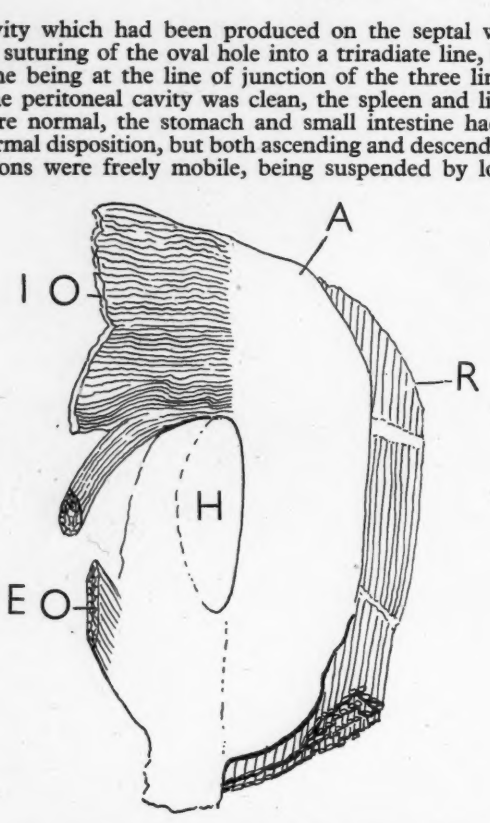

FIG. 424.—Drawing of specimen from ventral aspect. R, Lateral part of rectus abdominis; A, Anterior wall of rectus sheath continuous with Spiegel's line; I O, Obliquus internus; E O, Remnant of obliquus externus; H, Hernial orifice in lower part of linea semilunaris.

mesenteries. There was a deficiency in the falciform ligament of the liver, giving a large foramen in this structure. The septum in which the hernial orifice had been situated extended from the costal margin above to the crest of the ilium below, and from the erector spinæ behind to the rectus muscle in front. The septum was excised for detailed anatomical examination.

THE SPECIMEN.—The specimen received in the Anatomy Department consisted of a portion of the abdominal parietes extending from near the middle line anteriorly backwards as far as the mid-axillary line. No part of the costal margin or of the ilium was present. The abdominal aspect presented an oval opening, partially closed by sutures, with its long axis directed supero-inferiorly. The anterior margin of the opening was thick, fleshy, and loaded with extraperitoneal fat. The superficial aspect of the specimen was formed by the aponeurotic structures associated with the obliquus externus and rectus abdominis, with fragments of the obliquus externus muscle.

Dissection revealed that the rectus abdominis was fully developed and abnormally broad. Two tendinous intersections, incompletely dividing the muscle, were present in the portion of the muscle neighbouring the hernial opening. The linea semilunaris separating the lateral border of the rectus from the medial edge of the obliquus internus was present only opposite the upper third of the former muscle. The 'linea', however, is about 25 mm. broad, thus forming an aponeurosis (Spigelian aponeurosis). Opposite the lower two-thirds of the rectus the 'linea' is represented by an oval opening, bounded above by the lower end of the above-mentioned aponeurosis and below by the iliac crest. Medially, the rectus sheath bounded the opening, whilst laterally are fibres of the obliquus internus arching upwards to meet the Spigelian aponeurosis.

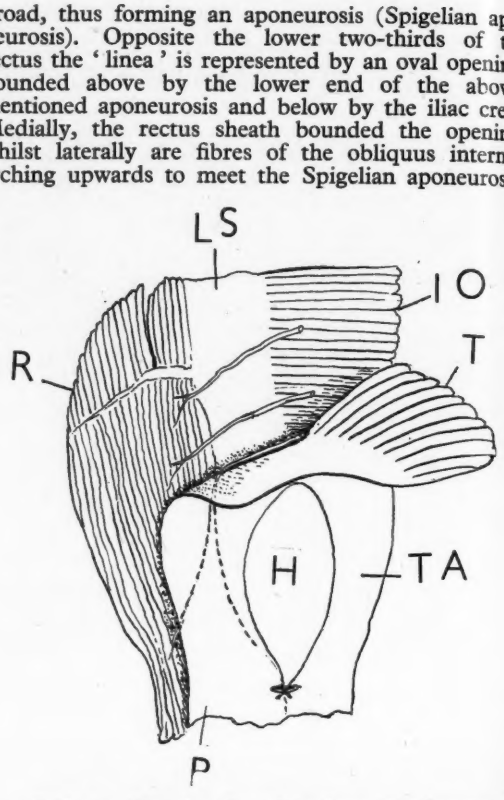

FIG. 425.—Drawing of specimen from dorsal aspect. R, Rectus abdominis; L S, Linea semilunaris spigelii; I O, Obliquus internus; T, Transversalis abdominis reflected downwards to expose intercostal nerves; P, Posterior wall of rectus sheath; T A, Transversalis aponeurosis covered by peritoneum; H, Hernial orifice.

Superficial to this, fibres of the obliquus externus descended almost vertically to end in an aponeurosis which sweeps towards the medial side of the hernial opening to join the rectus sheath (*Fig.* 424).

The fibres of the transversalis abdominis are disposed much as those of the obliquus internus, the upper fibres being transverse and the lower becoming increasingly vertical in direction as they are traced downwards. Near the upper end of the hernial orifice they become tendinous, forming a strong upper boundary to the neck of the hernial sac (*Fig.* 425).

Portions of three intercostal nerves appear between the transversalis and obliquus internus. These were probably the seventh, eighth, and ninth. The lowest of the three was found in the free margin of the hernial opening, and, after winding over its upper boundary, proceeded medially and divided into two descending branches.

SUMMARY AND CONCLUSIONS

A case of hernia of a large portion of the abdominal contents through a deficiency in the abdominal parietes corresponding in position to the linea semilunaris is described and an anatomical study of the deranged parts commented upon.

It would appear that the parietal deficiency was congenital and therefore due to an error during development. The error must have

occurred very early in embryonic life and is to be considered as a failure on the part of a local area of the mesoderm of the body wall to differentiate into its proper proportion of aponeurosis and muscle. A region was probably retained in an embryonic state, and this, after the development of a certain degree of intra-abdominal pressure, favoured the expulsion through it of, or the evagination of it by, coils of intestine, thus producing a hernial sac communicating through the linea semilunaris.

BIBLIOGRAPHY

ANGELETTI, E., *Arch. ital. di Chir.*, 1927, **17**, 38.
ANZILOTTI, G., *Ibid.*, 1938, **50**, 107.
AYZENSTEIN, I., *Vrach. delo*, 1928, **11**, 116.
BACHY, G., *Rev. de Chir.*, 1937, **75**, 201.
BINDER, A., *Morphologie der Missbildungen des Menschen und der Tieres* (Schwalbe), 1927, **3**, 60.
BONETTO, E., *Riforma med.*, 1938, **54**, 875.
BRANDTNER, C. E., *Arch. f. Orthop. u. Unfall. Chir.*, 1933, **33**, 219.
COSTA, G., *Arch. ital. di Chir.*, 1933, **34**, 705.
DERYCKE, P., *Bruxelles méd.*, 1938, **18**, 851.
DICK, E., *Gyógyászat*, 1930, **70**, 675.
FOURNIER, R., *Bull. Soc. d'Obst. et de Gynécol.*, 1933, **22**, 695.
GOYENA, J. R., *Semana méd.*, 1926, **2**, 1324.
GRECO, G., *Riforma med.*, 1936, **52**, 1309.
IPARRAGUIRRE, C. A. LEONI, *Rev. de Cir. de Buenos Aires*, 1938, **17**, 483.
JUNET, W., *Helvet. med. Acta*, 1937, **4**, 403.
LOBELLO, F., *Riforma med.*, 1934, **50**, 525.
MASSABUAU, A. GUIBAL, and CABANAC, *Arch. Soc. des Sci. méd. et biol. de Montpellier*, 1933, **14**, 340.
ODES, L. A., *Vestnik. khir.*, 1936, **44**, 49.
PAMPARI, D., *Arch. ital. di Chir.*, 1934, **37**, 619.
PAPIN, F., *Bordeaux chir.*, 1936, **7**, 203.
POZZI, G., *Boll. d. spec. med. chir.*, 1931, **5**, 267.
RIVER, L. O., *Ann. of Surg.*, 1942, **116**, 405.
RÖDÉN, S., *Hygiea*, 1930, **92**, 861.
SCOPINARO, A. J., *Semana méd.*, 1935, **1**, 284.
SEARA, P., *Día. méd.*, 1938, **10**, 972.

A CASE OF POLYPOSIS INTESTINI

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THE following case is here presented because the entire length of the large gut was affected, and because of the coincidence of an ectodermal (ichthyosis) and entodermal (polyposis) lesion.

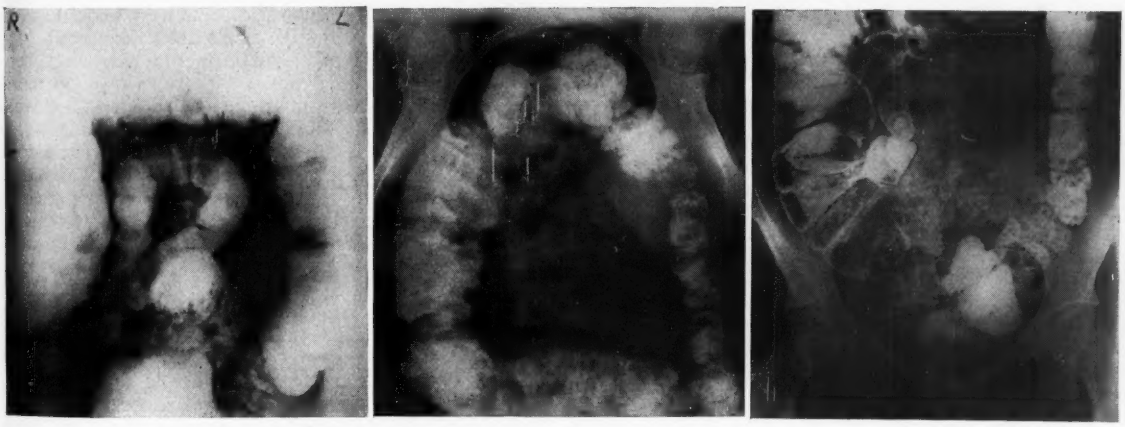
CASE REPORT

Miss S. Y. (21 years old), never having been previously ill, entered the A.T.S. eight months ago, and her symptoms date from that time onwards.

In November, 1942, she was admitted as a case of colitis, the main complaint being the passing of blood and mucus and occasional attacks of diarrhœa.

She looked pale and ill. Her hæmoglobin was 67 per cent, but she had no diarrhœa, and it was only several days after her admission that she passed blood-stained mucus for the first time.

Her skin showed ichthyosis of a mild degree everywhere, with the exception of the face, the palm



A B C

FIG. 426.—Serial radiographs taken after a barium enema. A, Areas of polyposis are seen in the sigmoid. The enema is seen to run straight through the incompetent ileocæcal valve into the ilium. The ilium itself seems to be free of polypi. B, Shows the whole length of large gut affected. C, Remains of the barium enema, collected in the recesses between the polypi, show the honeycombed appearance of the large gut well. The last few inches of the ilium are still filled.

Her family doctor, however, reports that he attended her for gastric influenza and melæna in 1940. The discrepancy between these two statements is explained by the fact that the patient's intelligence is unusually low.

of the hands, and the soles of the feet, the condition being most noticeable over the chest and abdomen.

The descending colon seemed to be in a continual state of spasm. It could, on each examination, be felt in almost its entire length.

Examination of the anus showed one polyp, well covered with epithelium, protruding. There were no hæmorrhoids.

Sigmoidoscopy revealed the lining of the large intestine studded, as far as one could see, with an incredible number of polypi of 1–5 mm. length, and X-ray films, taken at different stages of a barium enema, seem to show that the entire length of the large intestine is affected. (*Fig.* 426.)

It was also noted that, although no undue pressure was exerted, part of the barium enema ran straight through the iliocæcal valve, filling the lowest loop of the small gut, which seems to be free of polypi.

As Dukes and others have pointed out, this condition is inherited as a Mendelian dominant. Attempts, kindly made by Dr. J. W. Kemp, Kingston-on-Thames, to trace any relevant cases in this girl's family have so far produced no result.

REVIEWS AND NOTICES OF BOOKS

The 1942 Year Book of Industrial and Orthopedic Surgery. Edited by CHARLES F. PAINTER, M.D., Orthopedic Surgeon to the Massachusetts Women's Hospital and Beth Israel Hospital, Boston. 7 × 4⅝ in. Pp. 424, with 302 illustrations. 1943. Chicago: The Year Book Publishers Inc. (London: H. K. Lewis & Co.) 19s. net.

THIS useful little year book will maintain its popularity because it contains concise pithy articles of all important advances that have been made in this branch of surgery during the last year. The illustrations are clear, well chosen, and well reproduced.

In these days of overwork and war strain such a book as this will prove of real value not only to surgeons in the fighting forces but also those who are looking after the civilian war casualties.

Traumatic and industrial surgery are to the fore these days and this small volume should come into its own. A very useful book.

The Catechism Series. Surgery, Parts III–V. Fifth edition. 7¼ × 4¾ in. Pp. 141–376. Each part, 1s. 6d. net. **Anatomy,** Part V. By C. R. WHITTAKER, F.R.C.S.E., F.R.S.E. Fifth edition. 7¼ × 4¾ in. Pp. 76. 1s. 6d. net. 1943. Edinburgh: E. & S. Livingstone.

THE reader's attitude in regard to a catechism should be "to read, learn, mark, and inwardly digest". To our way of thinking the fare here may, however, prove rather too concentrated to be readily digestible, but the fact that this series of volumes is popular with many students is testified by its reaching a fifth edition. The author's name, Mr. Charles R. Whittaker, of Edinburgh, appears in the volume on anatomy, but those of surgery are anonymous. Fault may be found with some definitions, e.g., "cerebral irritation [Surgery, Part V, p. 303] is the name given to a state of hyperirritability of the brain which follows recovery from concussion." However, for the most part there will be general agreement with the answers provided to the questions. The little volumes are well printed and set out. They may also be described as supercharged.

Recent Advances in Anæsthesia and Analgesia (including Oxygen Therapy). By C. LANGTON HEWER, M.B., B.S. (Lond.), D.A. (R.C.P. and S. Eng.), Senior Anæsthetist, St. Bartholomew's Hospital, etc. Fourth edition. 8 × 5¼ in. Pp. 341, with 135 illustrations. London: J. & A. Churchill Ltd. 18s. net.

THE first edition of this book was published in 1932. It was an innovation in anæsthetic literature in that the author set out to achieve a definite purpose in providing a summary of recent advances, whilst omitting both elementary teaching and well-known methods of administration. This break away from the tradition of text-books was welcome and successful, and it may be stated without fear of contradiction that no library of books dealing with the subject of anæsthesia is complete without this volume. Numerous anæsthetic agents and varying techniques of administration have been introduced during the last decade, and these have been faithfully recorded in editions appearing in 1937 and 1939.

This fourth edition is, in our opinion, the best of the series. It contains valuable new subect matter, and much skill is apparent in its condensation and merging into the existing text.

The author makes two statements in his preface which are good to see in print, for it is time attention was drawn to them. The first deals with the absence of any chapters specially devoted to anæsthesia in military or air-raid casualty practice. Dr. Hewer observes: "It is evident that there is no essential difference in the principles of anæsthesia in peace or war, and any attempt to separate them or to provide easy short cuts to meet war-time conditions is more likely to prove a retrogression than an advance". The second observation deals with the regrettable fact that different manufacturing firms are permitted to call identical drugs by proprietary names. The author writes: "The position has now become more serious since many British firms are making products formerly marketed only by Continental manufacturers, and are calling the drugs by their own proprietary names. Three examples might be cited. One well-known intravenous anæsthetic is known under eight names besides its chemical formula, an analeptic under four, and a local analgesic under no less than nine appellations. The danger of confusion where the doses of similar-sounding preparations are widely different is obvious, and a doctor has already been found negligent for giving a fatal dose of a local analgesic which he thought was another with a similar name. Fatalities are bound to continue until makers are compelled to label their products plainly with the 'official' name, putting after it in brackets and in smaller type their own name or trade mark".

The dangers which Dr. Hewer indicates are very real ones, and we venture to express the pious hope that these lines may attract the notice of those in authority at the Home Office and of the British Pharmacopœia Commission.

A valuable feature of this book is the extensive and accurate bibliography found at the end of each chapter, enabling the reader to secure with ease further information on any particular subject.

The book is of real value to teachers of anæsthetics, senior students, and post-graduates reading for the D.A. examination. Many new illustrations appear in this edition, and the text is well arranged and

clearly printed. Both author and publishers are to be congratulated on maintaining such a genuine record of recent advances in anæsthesia and analgesia.

Illustrations of Surgical Treatment. Instruments and Appliances. By ERIC L. FARQUHARSON, M.D., F.R.C.S.E., Major, R.A.M.C., late Tutor in Clinical Surgery, Royal Infirmary of Edinburgh. Second edition. 9½ × 6 in. Pp. 392 + xii, with 317 illustrations and 63 plates. 1942. Edinburgh: E. & S. Livingstone. 25s. net.

THE first edition of this book has already achieved a wide and deserved popularity largely because of the excellence of the sections devoted to practical orthopædic methods and the treatment of fractures. This edition has been slightly enlarged, partly by an amplification of the sections on Infusion and Transfusion. These chapters have now been brought up to date by the inclusion of descriptions of the apparatus issued by the Army Supply Depot and the Emergency Medical Service, and their utility is thereby enhanced. The main body of the work is still given up to the treatment of injuries of bones and joints and some deformities. The illustrations, which are nearly all from photographs, are so well chosen and clear as to demand a relatively small amount of text; they enable the reader to follow the methods of treatment suggested quickly and easily, and their essentially practical nature should make them of the greatest value to the house surgeon. The section on injuries of the spine now includes a description of the use of skull-traction callipers for cervical dislocation, and much new matter has been added to the important subject of injuries of the hand and fingers. It is somewhat surprising that no mention is made of fracture of the head of the radius, which is a fairly common injury. The illustrations of surgical instruments have been increased; some of the urethral instruments shown are of historical interest only.

The book is beautifully produced, and the illustrations are so good that they can be used with an epidiascope for teaching the fundamentals of fracture treatment to large classes of students. It is a work which has already proved of the greatest value to students, house surgeons, and teachers of practical surgery, and the publication of this edition will make it even more popular.

Surgical Diseases of the Spinal Cord, Membranes, and Nerve Roots. Symptoms, Diagnosis, and Treatment. By CHARLES A. ELSBERG, M.D. With chapters by CORNELIUS G. DYKE, M.D., and ABNER WOLF, M.D. 10 × 7 in. Pp. 598 + x, with 249 illustrations. 1942. London: H. K. Lewis & Co. Ltd. £4 net.

THE production of a text-book on his subject by one who has devoted his life to its study must always be a matter for general satisfaction. Such an account of personal experience is invaluable to other workers in the same field. Elsberg's previous publications on the surgery of the spinal cord have been definite contributions to the subject, and this new and larger work is of equal interest and will form a valuable work of reference for those dealing with the surgical diseases of the spinal cord.

The book deals with every form of spinal disease which interests the neurosurgeon. There are short chapters on the anatomy and physiology of the spinal cord. Congenital abnormalities and injuries of the spine are briefly dealt with. There are also chapters dealing with the treatment of intractable pain and the spastic diseases of the extremities. The technique of spinal-cord surgery is described, and useful information on the post-operative care in these cases is given.

The greater part of the work deals with the tumours which give rise to compression of the spinal cord. These receive a detailed description, and it is here that the vast experience of the author is so valuable. His views are largely based on a personal series of 275 cases of spinal tumour verified at operation. Included in this section is a long chapter dealing with the pathology of spinal-cord tumours.

One of the most valuable features of the book is a section dealing with the X-ray diagnosis of diseases of the spinal cord and vertebræ. Like the pathological section, this is profusely illustrated. As the author suggests, these two sections written by collaborators can be regarded as monographs and atlases dealing with the respective subjects.

The book is beautifully produced and illustrated, and is a welcome addition to neurosurgical literature.

A Textbook of Gynæcological Surgery. By Sir COMYNS BERKELEY, M.A., M.C., M.D. (Cantab.), F.R.C.P., F.R.C.S., M.M.S.A. (Hon.), F.R.C.O.G., and VICTOR BONNEY, M.S., M.D., B.Sc. (Lond.), F.R.C.S., F.R.A.C.S., M.R.C.P. Fourth edition. 9¾ × 6⅛ in. Pp. 912 + xii, with 574 original drawings by Victor Bonney, and 17 colour plates. 1942. London: Cassell & Co. Ltd. 50s. net.

IT speaks well for the energy and enterprise of the authors and publishers that a fourth and new edition of this valuable text-book should be published in the midst of the greatest human cataclysm that mankind has ever experienced. It is, however, well that thoughtful surgeons should have their ideas directed towards the repair and cure of human ills which will still be necessary whatever new order may emerge from the present chaos.

First published in 1911, this book supplied a long-felt need both amongst gynæcologists, whose specialty owes so much to the authors, and to the general surgeon who from time to time is called upon to do gynæcological operations.

Gynæcological surgery is now well established as a specialty, but, like any other surgical specialty, it is founded on the principles of general surgery. This fact is stressed throughout the whole of the book, which as the authors state in the preface "sets forth in detail the indications for gynæcological operations, the pre-operative treatment, the possible complications . . . and the remote sequelæ as we have experienced them". The immediate post-operative treatment and complications are also discussed.

It is, moreover, truly a guide, comforter, and friend to the young surgeon, in that it gives not a series of different methods, but one, or at most two, which the authors have found the best. The details of the operations are given step by step; one does the operation and meets the possible difficulties while reading the text. The dangers are listed and the methods adopted by the authors to combat them after thirty-eight years of experience. Every step is illustrated by the clear-cut line drawings of one of the authors and not the confused photographs or imaginative illustrations so often seen in text-books on operative surgery. The coloured plates are well chosen and illustrate exactly what is seen as the pathological anatomy is unmasked.

The book begins with a prologue on the attributes of a good surgeon. It is a modern paraphrase of the views expressed by Guy de Chauliac in the sixteenth

century, who wrote, " Let the surgeon be well educated, skilful, ready and courteous. Let him be bold in those things which are safe, fearful in those that are dangerous, avoiding all evil methods and practices ".

It closes with an epilogue of encouragement to the young surgeon, but also reminds him that he has chosen a strenuous calling, the closing lines being :—

Does the road wind uphill all the way?
Yes, to the very end.
Will the day's journey take the whole long day?
From morn till night, my friend.

The authors, leaving nothing to chance, begin by describing and illustrating the instruments they have found most useful, the sterilization of material, the lay-out of the operating theatre, and the methods of suture and drainage when necessary; incidentally, they consider the abdominal route drainage more satisfactory than the vaginal.

The Reverdin needle, or Victor Bonney's modification, receives well-merited notice in all illustrations and descriptions. It is difficult to understand why this instrument has never been popular in this country. The more it is used, the more invaluable it becomes to every operator; the time it saves, alone, more than repays any slight difficulty which is first experienced by the operator and assistant in its use.

This is followed by their method of pre-operative examination in order to estimate the operative risk and margin of safety and the steps they take to render the patient safe for the operation. It would not, however, be generally agreed that two and a half minims of strychnine twice daily will in any way prevent operative shock. They agree it is unwise for a patient to know that the disease is malignant, as no matter how successful the treatment may be there is a " cancer dread " for the whole subsequent lifetime.

In considering cancer of the vulva the only operative procedure described is complete " scalpel " excision with removal of the glands from each groin. The results of radiotherapy, either by radium or deep X rays, might have at least been considered, and also excision by diathermy. The authors' experience of these alternative methods would be most valuable to the young surgeon. The same criticism applies when the advisability of Wertheim's operation for carcinoma is being described. The description is most meticulously careful in all details and the statistics as to the results most encouraging, but it must be remembered that the operators have the skill and experience of over 30 years to guide them. Moreover, the excision of the regional lymphatic glands would not be approved by many until it was fairly certain that the primary growth could at any rate be controlled by radiotherapy.

The description of McIndoo's operation (inlay grafting) for congenital absence of the vagina will enable many to get relief in this distressing condition.

It is refreshing to note that conservatism is so continually stressed, especially with regard to the ovaries. " It is important for the surgeon to realize . . . because the common apology for removing an ovary on slight provocation is that the patient has another to go on with." The classical error of removing the ovary through an " appendix incision " because " there is a cyst on it " is rightly condemned. On the other hand, though obviously the authors open every abdomen with a perfectly open mind, it is ultra-conservatism not to remove the appendix as a routine in order to save a further probable rather than possible operation. Ovarian cystectomy rather than ovariotomy is a great advance in conservative surgery.

The authors favour abdominal hysterectomy rather than vaginal, and conserve the cervix whenever possible; the latter, they insist, adds much to the subsequent well-being of the patient.

Hysterectomy is advocated as a routine when operating for malignant ovarian disease, but this is now very debatable as hysterectomy will not prevent a recurrence, and the uterus, if left, is an excellent container for radium needles if it should be necessary to use them, either as a prophylactic or curative agent subsequently.

They are not in favour of presacral sympathectomy for the relief of dysmenorrhœa or other intractable pelvic pain.

Every general surgeon could with advantage carefully study and practise the authors' operation for rectal prolapse and their modification of the Miles abdomino-perineal operation for rectal cancer.

The section on general abdominal surgery to enable the gynæcologist to deal with other pathological conditions found *en passant* is excellent.

The whole book is full of the results of ripe experience, careful thought, and infinite striving after the most stringent surgical ideals. It epitomizes the work of the gynæcological surgeon and not that of the surgical gynæcologist. It can be strongly recommended as a reference book for the general surgeon and a gynæcological vade mecum.

BOOK NOTICES

[*The Editorial Committee acknowledge with thanks the receipt of the following volumes. A selection will be made from these for review, precedence being given to new books and to those having the greatest interest for our readers.*]

Aids to the Investigation of Peripheral Nerve Injuries. M.R.C. War Memorandum, No. 7. Medical Research Council Nerve Injuries Committee. 9¾ × 6 in. Pp. 48, with 74 illustrations. 1942. London: H.M. Stationery Office. 2s. net.

The Hemorrhagic Diseases and the Physiology of Hemostasis. By ARMAND J. QUICK, Ph.D., M.D., Associate Professor of Pharmacology, Marquette University School of Medicine, Milwaukee, Wisconsin. 9½ × 6⅛ in. Pp. 340 + xx, with 24 illustrations. 1942. Springfield, Ill.: C. C. Thomas. (London: Baillière, Tindall & Cox.) 27s. 6d. net.

The Principles and Practice of War Surgery. With Special Reference to the Biological Method of Treatment of Wounds and Fractures. By J. TRUETA, M.D., Assistant Surgeon (E.M.S.), Wingfield-Morris Orthopædic Hospital, Oxford; Acting Surgeon-in-Charge, Accident Service, Radcliffe Infirmary, Oxford; Formerly Director of Surgery, General Hospital of Catalonia, University of Barcelona. 9¼ × 6⅛ in. Pp. 391 + xvi, with 136 illustrations. 1943. London: William Heinemann (Medical Books) Ltd., in conjunction with Hamish Hamilton Medical Books. 42s. net.

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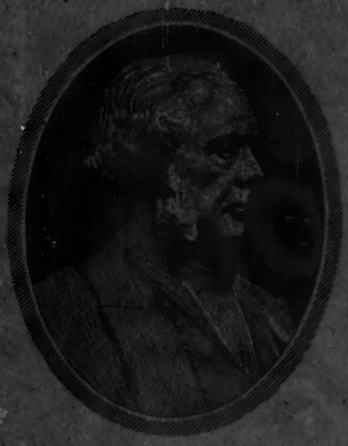

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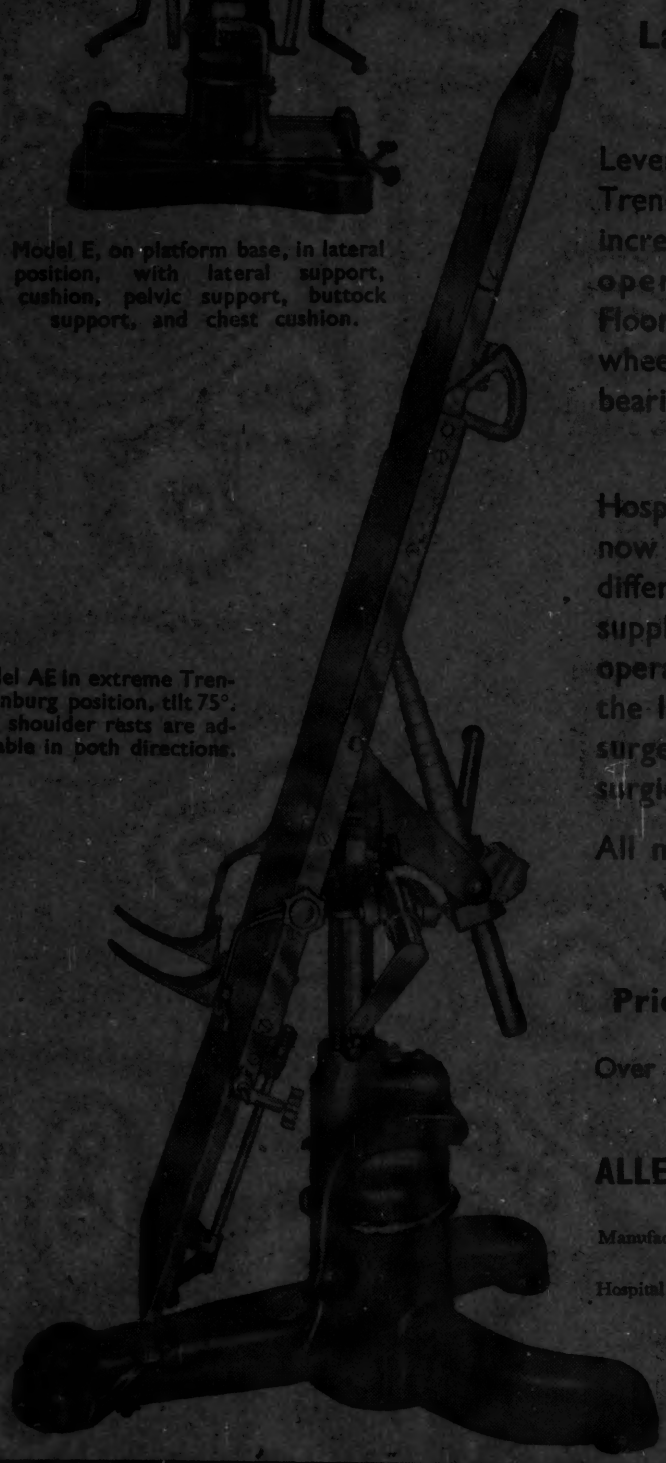

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